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CRITERIA OF DOWNWARD SULPHIDE ENRICHMENT.[1]

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INTRODUCTION.

Since 1899, when S. F. Emmons, C. R. Van Hise and W. H. Weed, bringing together and developing what had hitherto existed only as scattered suggestions, formulated the principles of secondary sulphide enrichment, the great importance of the process has received general recognition and such enrichment has been widely appealed to in explanation of the fact that many ore deposits, especially lodes, have a rich upper portion and deteriorate with increasing depth. With the details of the process itself this paper is not primarily concerned. It aims rather at a critical examination of the various lines of evidence by means of which the question whether or not the process has been operative in any given case may be answered. It is the outcome of a personal need, with which other students will perhaps sympathize, for some concise and orderly arrangement and evaluation of the criteria available for a decision. If the attempt is helpful in clarifying our ideas or serves but as a mere skeletal form about which a more nearly perfect expression of truth may crystallize, it needs no apology for its comparatively small leaven of originality.

[1] Paper read at the meeting of the Canadian Mining Institute at Toronto, March 2-4, 1910, and published with the permission of the Director of the U. S. Geological Survey.

A summary of this kind, moreover, may suggest lines of observation that can be pursued by those actively engaged in mining, who in their opportunity to study an ore body day after day as development proceeds have one distinct advantage over the geologist who ordinarily examines it at only one stage. The ability to see things accurately and honestly is a fundamental requisite to scientific research and every man engaged in mining may, if he chooses, advance our knowledge of ore deposits by recording with discrimination what he observes and knows to be true.

GEOLOGICAL EVIDENCE.

All the criteria to be considered are in one sense geological, but it is proposed under the present head to discuss first the broader relations of the ore bodies to topography, general structure and geologic history.

In a study of the ore deposits of a district the hypothesis of downward enrichment is likely to be first suggested by an observed relation of the present topographic surface to certain changes, common to a number of deposits, in the kind of ore with increase of depth. Thus we may have, as in many of the western copper deposits, leached ferruginous gossans under which are bodies of chalcocite ore grading downward into disseminated cupriferous pyrite; or, as in the Breckenridge district, Colorado, veins in which the characteristic ore of the upper levels is argentiferous galena, more or less altered to cerusite, while in the lower levels sphalerite and pyrite become increasingly abundant. It is not always easy to ascertain whether an observed downward change in character of the ore deposits of a given district is significantly related to the topographic surface. Determination of the question requires considerable mining development. Moreover, the relation between vertical ore sequences and the topographic surface, even where topography and changes in ore are genetically connected, is likely to be so irregular that the geologist may remain in some doubt as to whether the apparent relation has any real significance. The answer to this question will in general be clearer the stronger the surface relief.

If in a district of pronounced relief there is a recognizable

correspondence between topography and successive ore zones as found by vertical development, the next important step in the investigation appears to be the determination, if possible, of the general relation of the present topography to that in existence when the ore bodies, or the lean materials from which these have resulted, were deposited. Evidently if the first deposition took place when the topography was similar to that now existent, the observed relations of ores to surface may be due to causes entirely independent of downward enrichment. On the other hand, if it can be shown that the original ore deposition long antedated the development of the present land forms, that many hundreds or thousands of feet of rock have been removed by erosion since the formation of the veins, then the observed relations of ores to surface becomes very strongly suggestive of downward enrichment. The operation of this process becomes demonstrable if it can be further shown that the original ore deposition and the general position and configuration of the present surface have not been both determined by some antecedent factor, such as, for example, the occurrence of beds of quartzite particularly favorable for the deposition of certain kinds of ore and especially resistant to erosion. Other less simple conditions are conceivable that might determine ore deposition within a zone having a certain vertical range and which might long afterward result in bringing the topographic surface into general coincidence with this zone. Here, as in most other geological problems, extreme or ideal conditions will seldom confront the investigator; he will be called upon to draw conclusions from facts that are more or less obscure and from evidence that rarely points unwaveringly to the truth.

Another group of criteria that may be considered here are those derivable from the general relations of a zone of sulphide enrichment to the overlying zone of oxidation. The mere presence of a deep, oxidized and leached cap, suggests that enrichment will be found below. Where such a gossan is directly underlain by an ore body that grades downward into low-grade material the geologic evidence of enrichment is complete.

As Weed[1] has pointed out, "enrichment is largely dependent upon the presence of marcasite, pyrite or some other form of iron sulphide in the primary ore, since lixivation depends upon the iron sulphates and precipitation is mainly effected by the unaltered sulphides." It appears highly probable that this is not the only type but that some enrichment may take place in deposits nearly free from pyrite through reactions not involving large quantities of iron sulphates. Yet the best known and most authentic examples of the process are those in pyritic deposits and consequently we may regard leached gossans containing abundant limonite or hematite as useful geologic indications of enrichment below.

If this process has been effective the sulphide ores below should have certain definite relations to the oxidized material above. The vertical succession of sulphides below the limit of oxidation should be in general the same in each deposit. Moreover, each variety of sulphide ore should under normal conditions be at approximately the same distance below the oxidized zone or should occur at depths whose variation from the normal is explainable by special circumstances favoring or opposing the downward penetration of solutions from the leached portion of the deposit.

In arid regions where the ground water lies deep and has probably undergone fluctuations in level both oxidation and enrichment may exhibit great irregularity in vertical range and yet maintain an obvious close relationship. Thus at Bisbee, where much of the oxidation may date from pre-Cretaceous time and where the groundwater has probably undergone several changes in level, oxidation has extended to the extraordinary depth of at least 1,400 feet while sulfide ores are found within 200 feet of the surface. The enrichment of these residual masses, however, has proceeded in general from their peripheries inward or from later fissures outward and is just as clearly the result of solutions emanating from the oxidized parts of the ore bodies as is the case in the well-known deposits at Ducktown, Tenn., where the enriched layer is thin and conforms in general to a shallow, stable and fairly uniform ground water level.

[1] "Enrichment of Gold and Silver Veins," *Trans. Amer. Inst. Mng. Eng.*, vol. 30, 1901, p. 439.

MINERALOGICAL CRITERIA.

Obviously if we were able to conclude that certain metallic sulphides or certain gangue minerals associated with sulphides in unoxidized ores are formed only at low temperature by downward-moving solutions we should have a ready means of distinguishing those deposits in which descending enrichment has taken place. Unfortunately, however, most of the minerals found in ore deposits appear to be capable of forming under varied conditions of environment, of temperature and of depth or pressure. Thus in the useful lists prepared by Lindgren[1] and by W. H. Emmons[2] there are very few minerals, outside of those characteristic of the zone of oxidation, that so far as we know are rigidly limited to any one division of the whole vertical range of formation exhibited by the minerals associated in ore deposits. In Lindgren's list covellite (CuS) is the only sulphide peculiar to the lower groundwater zone or zone of sulphide enrichment. Chalcocite (Cu_2S) is given as characteristic of this zone but is doubtfully included also in the "middle and upper vein zone" and in the "deeper vein zone." Stephanite (Ag_5SbS_4) and polybasite (Ag_9SbS_6) are both given as occurring in the zone of sulphide enrichment but are doubtfully listed also in the "middle and upper vein zone." Among the gangue minerals, kaolin is recognized only in the zone of sulphide enrichment and in the oxidized zone. In Emmons's table the minerals occurring in the zone of sulphide enrichment and in the oxidized zone are not distinguished. He notes chalcocite not only as occurring in "deposits of moderate and shallow depth" but also in "deposits of the deep vein zone." In his table no sulphide appears as definitely diagnostic of the zone of downward sulphide enrichment. In another place W. H. Emmons,[3] following L. C. Graton,[4] refers to the chalcocite of the Virgilina district in Virginia and

[1] "The Relation of Ore-Deposition to Physical Conditions," ECON. GEOL., Vol. II., 1907, pp. 105–127.

[2] "A Genetic Classification of Minerals," ECON. GEOL., vol. 3, 1908, pp. 611–627.

[3] "Some Regionally Metamorphosed Ore Deposits and the So-called Segregated Veins," ECON. GEOL., vol. 4, 1909, p. 772.

[4] "Mineral Resources," U. S. Geol. Survey, 1907, part 1, p. 620.

North Carolina as original, and remarks that in that locality alone, so far as he is aware, has primary chalcocite been found. But inasmuch as Weed[1] had previously shown convincingly that some at least of the Virgilina chalcocite is secondary this supposed exception to the general occurrence of the mineral as a result of sulphide enrichment has remained a little doubtful.

Since this paper was read before the Institute, Mr. F. B. Laney has presented before the Geological Society of Washington[2] the results of a microscopical study of the Virgilina ores. He finds that chalcocite occurs in them partly as veinlets of secondary origin traversing older bornite and partly as intimate intergrowths with the bornite. These intergrowths prove that a part of the chalcocite is as old as the bornite. The intergrown bornite and chalcocite occur in the deepest workings, down to about 500 feet, and there is no direct evidence that they have resulted from the alteration of chalcopyrite. There is, however, a possibility that both minerals are secondary. One ground for considering all of the chalcocite at Virgilina as an original constituent of the veins appears to be the fact that it is enclosed in solid coarsely crystalline quartz supposedly impervious to downward-moving solutions. The validity of this reasoning will be considered later.

Of great interest in this connection is the occurrence of chalcocite in the Paleozoic and Mesozoic sandstones of New Mexico, Colorado, Utah and adjacent states.[3] Lindgren and Graton, in a report on the ore deposits of New Mexico now in press, discuss the genesis of these deposits and, after showing that they are not significantly associated with igneous rocks or deep fissuring, reach the conclusion that the chalcocite associated in some places with pyrite, chalcopyrite and bornite, has been deposited contemporaneously with the other sulphides and is not a product of enrichment. They believe, however, that the deposits are due to concentration by waters of atmospheric origin charged with sulphates

[1] "Enrichment of Gold and Silver Veins," *Trans. Amer. Inst. Min. Eng.*, vol. 30, 1901, p. 433, fig. 2.

[2] Meeting of March 9, 1910.

[3] See Emmons, S. F., "Copper in the Red Beds of the Colorado Plateau Region," Bull. U. S. Geol. Survey No. 260, 1905, pp. 221–232.

and chlorides, deposition being effected by reduction brought about in part by organic material. Accordingly this chalcocite while not, strictly speaking, the result of downward sulphide enrichment has been formed under analogous conditions as regards temperature, pressure and kind of solution. A similar explanation probably applies to the occurrence of disseminated chalcocite in the lower Cretaceous Glance conglomerate at Bisbee, the copper in the conglomerate having been derived from the great deposits in the Paleozoic limestones and concentrated by meteoric waters.

So far as our present knowledge of its occurrence goes, I believe that we are justified in regarding chalcocite as a mineral very rarely if ever formed except under the conditions of downward sulphide enrichment or by vadose sulphate solutions. Of course any such generalization is liable to be overturned by new evidence but the burden of proof appears to rest at present upon those who support the view that chalcocite can be deposited simultaneously with quartz and pyrite or other sulphides characteristic of unmodified or primary veins. Outside of the two copper sulfides, covellite and chalcocite, there are no minerals that so far as we know at present, are peculiarly the products of sulphide enrichment, although there are a number the presence of one or more of which in any ore body is distinctly suggestive of that process. Among these may be mentioned the silver minerals argentite, proustite, pyrargyrite, stephanite, polybasite and probably a goodly number of the more complex sulpharsenites and sulphantimonites. It is quite possible that farther study of ore deposits may result in showing that some of these minerals, especially proustite, are fully as characteristic of downward enrichment as is chalcocite.

Marcasite is listed by Lindgren as a mineral of the "middle and upper vein zone" while Emmons places it not only in these zones but also among the secondary minerals in the zone of oxide and sulphide enrichment. The researches of E. T. Allen[1] and his colleagues of the Geophysical Laboratory of the Carnegie Institution have shown that while pyrite is a stable form at all

[1] Oral communication.

except possibly very high temperatures marcasite is a form taken under certain conditions by the disulphide of iron at low temperatures, the inversion point between the two, under the conditions of the experiments being, in the neighborhood of 400° C. This indicates that if during the process of sulphide enrichment it is possible for the disulphide of iron to separate from solution it may take the form of marcasite rather than pyrite. Consequently the presence of marcasite in an ore deposit, although this mineral may in some cases be an original constituent in veins formed under moderate pressure and temperature, affords a strong suggestion of enrichment by descending solutions.

There is considerable evidence to show that bornite and chalcopyrite may in some cases be secondary with reference to associated pyrite but as both minerals are certainly primary in many contact-metamorphic deposits their mere presence in an ore body is of no value as a criterion of enrichment. Tetrahedrite, enargite and numerous other sulpharsenites and sulphantimonites are also of doubtful utility as criteria in our present stage of knowledge.

Kaolin, according to Lindgren,[1] occurs only in the oxidized zone and in the zone of sulphide enrichment. If this be true the association of kaolinite with metallic sulphides constitutes a most useful criterion for the recognition of downward sulphide enrichment. In the Silverton district of the San Juan region of Colorado, however, kaolinite appears to have formed contemporaneously with abundant, well-crystallized pyrite and with bournonite, enargite, guitermanite ($3PbS.As_2S_3$) and zunyite ($[Al(OH, F, Cl)_2]_6Al_2Si_3O_{12}$), on Anvil Mountain near Silverton. It occurs also in the same district in the Yankee Girl and near-by mines, associated with pyrite, chalcopyrite, bornite and stromeyerite. In a report[2] on the Silverton district published in 1901 the bonanzas of the Yankee Girl and other mines near Red Mountain were ascribed to downward enrichment but a part of the kaolinite was supposed to be of hydrothermal origin. I am

[1] "Ore-deposition and Physical Conditions," ECON. GEOL., Vol. 2, 1907, p. 120.

[2] Ransome, F. L., "Economic Geology of the Silverton Quadrangle, Colo." Bull. U. S. Geol. Survey, No. 182.

not at present inclined to adhere strongly to the latter view, but recognize the possibility that the kaolinite may have been formed from sericite by acid solutions descending from an overlying zone of oxidation. The occurrence of kaolinite with alunite, quartz, pyrite, famatinite, bismuthinite, gold tellurides and native gold at Goldfield, Nev., is rather more difficult to account for by the hypothesis of ordinary downward sulphide enrichment, as has been shown in another place.[1] The hypothesis offered in explanation of the origin of the Goldfield ores, however, namely that of simultaneous solfatarism and oxidation, has so much in common with the process of downward sulphide enrichment that this exceptional occurrence of kaolinite does not conflict seriously with the view that the mineral is very rarely formed except in the zone of enrichment.

The very common gangue mineral quartz is known to form under a wide range of conditions from those of ordinary atmospheric pressure and temperatures to those under which granitic rocks have solidified. It is true that Mügge,[2] following up Le Chatelier's discovery that quartz undergoes an abrupt change of volume at 570°, has shown that quartz at that temperature inverts to a second crystallographic form, distinguished as β-quartz, and that consequently it is possible to determine by refined optical methods whether a given quartz crystal was originally formed above or below the inversion temperature. This, however, does not help us to distinguish between quartz formed under hydrothermal conditions and high pressure in veins, and quartz formed by secondary processes in the zones of sulphide enrichment and of oxidation. While silica deposited near the earth's surface often assumes the form of opal or chalcedony the occurrence of quartz in geodes and of crusts of quartz over oxidized ore (in the Globe district, Ariz., for example, chrysocolla and malachite occur encrusted with quartz and traversed by veinlets of the same mineral) shows that high pressure and

[1] Ransome, F. L., "Geology and Ore Deposits of Goldfield, Nevada," Prof. Paper No. 66, U. S. Geol. Survey, 1909, pp. 192–193.

[2] "Ueber die Zustands änderung des Quarzes bei 570°," *Neues Jahrbuch fur min., etc.*, Festband, 1907, pp. 181–196.

temperature are not essential to the formation of this mineral. Consequently it does not appear safe to assume that because a given sulphide is enclosed in quartz the sulphide has remained unchanged since the vein was first filled. On the other hand, the contemporaneous deposition of metallic sulphides with chalcedony or opal may be assigned considerable weight as evidence that they are the result of downward enrichment or have been deposited very near the surface.

Calcite, barite and fluorite appear to have no definite significance as regards sulphide enrichment, being present in original deposits formed at great depth as well as in the zone of oxidation. In other words, calcite and fluorite are classed by Lindgren as persistent minerals and barite should probably be put in the same group.

Among the mineralogical criteria of enrichment should of course be included the pseudomorphous replacement of one mineral by another. That chalcocite can thus replace pyrite, chalcopyrite or bornite has been thoroughly well established by many independent observations. Where, as in the Miami-Inspiration ore zone at Globe, crystals of pyrite have been superficially altered to chalcocite while still retaining their crystallographic form, the evidence of enrichment is conclusive. The careful study of the mineralogical details of such indubitable cases of enrichment as those at Miami and Ray is likely to add much to our knowledge of mineralogical criteria for the recognition of the process. Assurance that the process has actually been operative affords us a secure vantage ground for further deduction as regards deposits whose origin is less certainly known.

In the absence from any deposit in question of any one mineral known to be characteristic of sulphide enrichment recourse must be had to the significance of an association of minerals which from our knowledge of their occurrence and paragenesis elsewhere are more or less suggestive of enrichment. Evidence of this kind, however, is, in our present stage of knowledge, inconclusive and must be weighed in connection with other criteria presently to be discussed.

Although in general we should expect minerals resulting from

downward enrichment to be formed at lower temperatures than those found in unmodified veins, yet it is possible that the solutions effecting enrichment may under some circumstances be warm or hot. In arid regions where the groundwater lies deep and the precipitation is slight the solutions percolating through the oxidized zone are likely to be of concentrated character and if pyrite, marcasite or chalcopyrite is abundant and if the mass is porous the chemical changes involved in oxidation may be so energetic as to develop considerable heat. This possibility suggests an explanation of the formation of specularite instead of or in association with limonite in certain gossans of arid regions as at the old Dominion mine near Globe. As Gágel and Stremme[1] have shown, the presence of salts in solution lowers the water tension and permits of the formation of hematite at low temperatures.

CHEMICAL CRITERIA.

Inasmuch as downward enrichment implies selective transfer and redeposition of material originally present in a deposit the result of the process may be studied chemically as well as mineralogically. One difficulty, however, lies in the fact that enrichment produces not merely a vertical gradation from rich ore to lean ore but effects a special kind of gradation by the super-position of one process upon another. A series of assays or chemical analyses may show that an ore body decreases in tenor below a certain depth, but such sampling as a rule is of little use in detecting the essential fact of superposition of processes, unless it can be shown also that the change in tenor has relations to certain mineral groupings, or to topography, ground-water level or zone of oxidation. It may be possible in future to recognize some characteristic chemical distinction between a vertical gradation due to enrichment and a vertical gradation due to physical and chemical conditions controlling original deposition. The nature of the difference, if any, is not at present apparent.

Since a deposit cannot ordinarily be enriched by constituents not originally present in at least small quantity in the primary

[1] *Centralblatt f. Geologie*, 1909, p. 472.

ore, comparison of chemical analyses of the enriched ore and the primary ore should throw some light on our problem. Unfortunately, however, it is rarely practicable to secure samples of ore that are entirely free from suspicion of having been to some degree affected by whatever enrichment is supposed to have taken place above. Evidence obtained in this way may, however, have value from its negative character. If, for example, certain veins characterized by an upper zone of rich gold tellurides are found to diminish in tenor downward and finally pass into pyritic material containing no trace of tellurium the gradation is probably one of original deposition and not of downward enrichment—I say *probably,* because there is a possibility that an enriched deposit may not have been originally of uniform character; downward enrichment may be superposed upon an ore deposit that had originally a rich upper portion.

Another mode in which chemical analyses or assays may be utilized is in attempting to calculate from the composition of enriched ore and of material representing as nearly as possible the supposed original deposit, the amount of erosion or the vertical range of oxidation necessary to effect the concentration exhibited by the ore body under investigation. Cases are conceivable in which it might be possible in this way to check the hypothesis of enrichment by reference to facts determinable from the general geology of the region. As a rule, however, the data will be insufficient to permit of this comparison.

Yet another way in which chemistry may aid in the detection of downward enrichment is in the study of wall rock alteration. While much has been done in the study of metasomatic processes in connection with original ore-deposition there has been as yet no careful study made of the chemical and corresponding mineralogical changes induced in the already altered wall rock by the generally descending solutions effective in sulphide enrichment. This line of investigation has its obvious difficulties and the instances where it can be successfully followed are undoubtedly rare. Nevertheless, the possibility of pursuing it when opportunities arise may well be kept in mind. Mineralogically the superposed effect upon the wall rock of solutions producing

downward sulphide enrichment is likely to be indicated by the alteration of sericite to kaolinite and in some cases by the development of alunite and diaspore.

TEXTURAL CRITERIA.

Under the heading of textural criteria of enrichment may be grouped a number of conditions directly observable with the naked eye or by means of the microscope in thin sections or on polished surfaces of ore. Among these may be mentioned the occurrence of veinlets of rich ore in leaner material, the encrusting of fragments of low-grade ore by shells of high-grade ore, irregular metasomatic replacement of one mineral by another, and evidence of solution followed by deposition of fresh material. Where these relations can be ascertained they constitute some of the most reliable criteria for establishing the fact of enrichment. Yet they cannot be taken by themselves since it is well known that ore deposits are often complex structures and that movement and fissuring following an initial period of deposition may be succeeded by fresh accretions of ore from deep sources, such additional material having no relation whatever to the process of downward enrichment. Evidently, therefore, the purely textural evidence must be weighed in connection with the mineralogical character of the freshly deposited material and with the relation of such deposition to erosion and to an overlying zone of oxidation.

In this place also belongs consideration of the degree of permeability of an ore body to percolating solutions. Obviously a highly porous ore, whether this porosity be original or the result of fracturing, will be more susceptible to extensive enrichment than a compact impervious one. Imperviousness, however, is often more apparent than real and is at best a relative property. Ordinarily vein quartz even when not visibly fractured may be readily permeated by solutions, as anyone knows who has tried to write upon a fragment with thin ink. Evidently time is an important factor here and in attempting to decide whether or not the material of a certain vein is so impervious as to rule out the possibility of enrichment some attention should be given to the

age of the deposit and the length of time available for the enriching process to have gone on. These considerations appear to be particularly applicable, for example, to the Virgilina veins, which are possibly Paleozoic or pre-Cambrian and which consequently may have been exposed to the action of downward-moving solutions for vast periods. Moreover, in the stresses to which such ancient veins must have been from time to time subjected, it is highly probable that the quartz has been microscopically fractured and has at some periods been more porous than at present. Specimens of chalcocite ore from the Virgilina district show that some of the chalcocite has undergone alteration to malachite although solidly embedded in quartz apparently as impervious as that from the deeper workings. In the Miami-Inspiration ore-bodies of the Globe district, moreover, many of the specks of chalcocite are solidly embedded in the silicified schist and in the veinlets of quartz, so that they have every appearance of being products of the earliest period of mineralization. Yet the evidence here is conclusive that these specks of chalcocite have resulted from the alteration of pyrite and chalcopyrite and probably in most cases exactly fill the space once occupied by the parent mineral. All stages may be seen from pyrite thinly coated with chalcocite to solid chalcocite. The enrichment, however, appears to have been accompanied by some solutions and deposition of silica and perhaps by some migration of the chalcocite in solution. Study of siliceous deposits that have undergone chalcocitic enrichment tends to prescribe caution in the use of apparent or present imperviousness of an ore body as an argument against the possible efficiency of the process, which appears to be capable of producing important results under conditions permitting only capillary or subcapillary movement of solutions.

CONCLUSIONS.

The criteria for the recognition of downward sulphide enrichment may be grouped as (1) geological, (2) mineralogical, (3) chemical and (4) textural.

The geological evidence most indicative of downward enrichment is progressive impoverishment of all similar sulphide de-

posits in any district with increase of depth. Complete demonstration requires, however, that the change in character of the sulphides should show dependence upon topography decidedly younger than that existing when the veins were originally formed. In other words, the change in the ores should be uniform in sequence or kind and should be dependent upon erosion and oxidation.

Among the mineralogical criteria, the presence of chalcocite or covellite is most nearly unequivocal. These minerals are not known to be deposited from thermal waters derived from great depth unless possibly some of the Virgilina chalcocite was so formed. Other minerals such as argentite, proustite, pyrargyrite, stephanite, polybasite and probably other complex sulpharsenites and sulphantimonites are suggestive of downward enrichment but their presence is not, so far as we know at present, proof of this process. Marcasite, as regards the problem in hand, has similar standing. Among the non-metallic minerals found in ore bodies kaolinite and alunite, although exceptionally they may be formed in the upper zone of hydrothermal activity, are generally significant of the work of descending waters. Quartz, calcite, barite and fluorite appear to be deposited by descending as well as ascending waters. Pseudomorphous replacement of one mineral by another may constitute a valuable criterion of enrichment but should be considered in connection with the possibility of a change in character of hydrothermal solutions rising from great depth.

Chemical criteria may reveal the fact of a progressive downward decrease in the tenor of an ore body but still fail as a rule to establish the essential characteristics of enrichment, namely a superposition of one process upon another. Chemistry may in future help us to recognize the action of enriching solutions by their effects upon the wall rocks. Chemical and mineralogical criteria obviously overlap in a very intimate way.

Textural criteria such as the encrusting or veining of one mineral by another, are likely to be of much value but should be weighed in connection with the mineralogical character of the freshly deposited constituents of the ore and with the relation

of such deposition to erosion and oxidation. The impermeability of an ore body is never absolute and in considering the possibility of downward enrichment attention should be given to the age of the deposit and to the length of time during which enrichment may have been operative. The argument that because a vein is now dense and apparently impervious it cannot have been enriched from above, is one to be used with caution.

COPPER IN THE "RED BEDS" OF OKLAHOMA.

WILLIAM ARTHUR TARR.

Though copper ores have been found in Permian and Triassic formations the world over[1] only a very few of the deposits are of economic value. A peculiar interest is attached to them because of the obscurity of their origin, and their occurrence in sedimentary formations in the Permian and Triassic periods.

During the past summer a new locality in which copper ore occurs in "Red Beds" of probable Permian age was visited by the writer. While only a limited time was spent on the examination it is thought a few notes on the occurrence would be of interest. In addition to its being another deposit to be added to those of this peculiar group which have already been described, the high values of gold and silver contained, and the occurrence of the ore replacing wood are important features.

The locality where the ores are found is about ten miles northeast of Stillwater, Payne County, Oklahoma, on the southeast quarter of section 22, township 20 N., range 3 E. The farm belongs to Mrs. M. J. Burwell. Copper was first discovered by the owner about 1901, but the discovery was withheld from general knowledge until about three years ago. Since then several attempts have been made by different people to develop the prospect. By these operations a shaft and a tunnel were opened, but at the time of examination only the tunnel was accessible and that was partly filled with water. Within an area of probably fifteen miles square, copper is reported to have been found in this vicinity during the sinking of wells.

TOPOGRAPHY.

The deposit lies in a region of youthful topography, the rolling hills which cover the country being cut into the irregular beds

[1] Beck-Weed, Vol. 2, p. 488 and pp. 497–499. E. J. Schmitz, *Trans. Amer. Inst. Min. Eng.*, Vol. 26, pp. 97–108, 1896.

of sandstones and shales. The larger streams parallel each other and flow southeast to the Cimarron River about twelve miles distant.

GEOLOGY.

Great difficulty has confronted geologists who have undertaken the task of finding the line of contact between the Pennsylvanian and the Permian because the Permian and the upper Pennsylvanian are barren of fossils. If the Wreford limestone be taken as the base of the Permian, as it is by Prosser,[1] and as is accepted conditionally by Gould,[2] the limestone in the vicinity of this copper deposit passes into a sandstone. From this point south across Oklahoma the line between the Pennsylvanian and the Permian is uncertain. The " Red Beds " that largely compose the Oklahoma Permian, extend east of the normal line of contact as an embayment in the Pennsylvanian, and this has given rise to the belief that the Permian and the Pennsylvanian interlap.[3] The deposit of copper lies almost exactly on the line of contact as traced by the Oklahoma geologists.

The " Red Beds " consist of sandstones and shales of a predominating red color. A striking feature in this vicinity is the extreme irregularity of the beds which thicken and pinch out locally. The sandstone is fine-grained, with its color varying from white, through yellow, to red, and it contains lenses of argillaceous sandstone. The grading of the Wreford limestone into sandstone and the irregular lenses of sandstone and shale indicate a change from deep water to shallow water.

THE DEPOSIT.

The tunnel previously mentioned is nearly sixty feet long, and fifteen feet from the entrance there is a crosscut about thirty feet in length on each side. The tunnel level is twenty-five feet below the surface.

[1] Prosser, C. S., "Revised Classification of Upper Paleozoic Formations of Kansas," Jour. Geol., Vol. 10, 1902, pp. 703–737.

[2] Gould, C. N., "Water Supply and Irrigation Paper," No. 148, 1905, pp. 28–32. Kirk, C. T., Third Bien. Report, Okla. Geol. and Nat. Hist. Survey, 1904, pp. 5–14.

[3] Kirk, C. T., *loc. cit.*

The ore occurs replacing fossil wood. The pieces are cylindrical, and vary in length from a few inches to several feet. The diameter ranges from one inch in the smaller pieces to six inches in the larger. Many small twigs and leaves are visible. Traces of the woody fibers can still be seen. The specimens seen in section consist of an outer portion of carbonaceous material and an inner portion of chalcocite. The carbonaceous material resembles charcoal, contains a large per cent. of moisture, and burns with difficulty. This material has acted as a filter and has become impregnated with copper salts. The fossil wood lies in a position conforming to the dip of the enclos-

FIG. 158. Showing network of veinlets with carbonaceous material between them. All the veinlets are malachite. = 1.

ing formation which is very slight, and at the same time the pieces are rudely parallel to each other. This indicates a close proximity to the shore and probably wave action. The major portion of the wood is contained in the sandstone, a small part is found in the argillaceous sandstone, and one small piece was found enclosed in quartzite.

The minerals observed were chalcocite, chalcopyrite, malachite, azurite and a little chalcanthite. Some calcite was associated with the ore.

As noted above the interior of the specimens consists of chalcocite surrounded by a zone of carbonaceous material. The chalcocite is pure, and wherever cracks or seams extend into it they are filled with malachite. In the carbonaceous zone there are two sets of veins, one running longitudinally and the other at right angles to the first. They are filled with malachite and azurite. These veinlets vary in size from the thickness of a sheet of paper

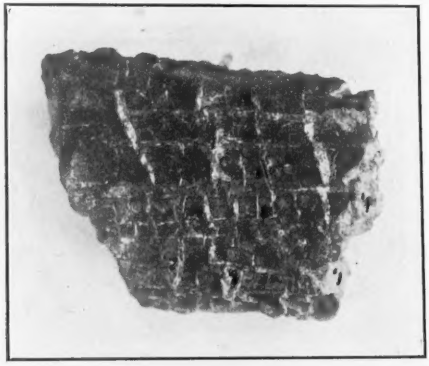


FIG. 159. Shows veinlets filled with chalcocite and malachite. Dark portions are carbonaceous material. 1 = chalcocite; 1′, = chalcocite on end of specimen; 2 = malachite; 3 = carbonaceous material.

to one sixteenth of an inch (see figures). The original chalcocite occasionally fills the thicker veins especially close to the interior (see Fig. 159). Small specks of malachite are disseminated through the sandstone immediately surrounding the wood. Where water was dripping from the roof a little chalcanthite was observed. This also shows that the present waters are acid.

Another common mode of occurrence is in the form of concretions, some of which attain a size of three inches in diameter. The interior of these concretions is chalcocite in most cases surrounded by a zone of chalcopyrite ⅛ to ¼ in. wide, though in

some instances the zone is incomplete. Thus the arrangement of these minerals is the reverse of their normal order, and so far as is known to the writer this has but rarely been observed for we ordinarily look upon chalcopyrite as the primary mineral. All of the concretions contain traces of woody material and also some carbonates.

As was noted above some patches of quartzite were observed. These were just below the wood and were doubtless caused by the alkaline waters from the wood, which carried the silica in solution. One small piece of wood was observed in this quartzite and it did not contain any copper ore, due no doubt to the imperviousness of the quartzite.

Assays of the chalcocite made in the assay laboratory of the University of Arizona showed a silver content of 31.25 oz. per ton and a gold content of .1 oz. per ton. These values in gold and silver are unusually high for this type of ore although some ores have been reported as carrying as high as ten oz. per ton of silver.[1]

ORIGIN.

The structure of the "Red Beds" of this vicinity indicates an inland bay. The streams which emptied into this bay brought in both metallic salts and fragments of wood. Under the arid conditions during the formation of the "Red Beds" the salts continued to accumulate and be precipitated by the organic matter in the water and many of the larger pieces of wood collected at the shore-line and were buried by the waves. This was the first concentration of the copper, but it was only a partial concentration, being too widely disseminated to be of economic value. The whole was deeply buried until subsequent erosion again brought it near the surface. A second concentration took place. The disseminated material was leached out probably as a sulphate, and again precipitated by the carbonaceous matter of the fossil wood. This time the cells of the wood were replaced one by one by the copper thus,

$$4CuSO_4 + 5C + 2H_2O = 2Cu_2S + 2H_2SO_4 + 5CO_2.$$

[1] Lindgren, W., Bull. 340, *U. S. G. S.*, pp. 170–174.

The limited amount of wood available to be replaced by the copper aided in making the second concentration complete. The CO_2 liberated by this reaction probably aided in dissolving out the SiO_2 necessary to form the quartzite. In the case of the concretions we have the chalcopyrite on the outside, due probably to the carbonaceous material acting as a membrane or solid absorbent. The well known property of carbon to absorb certain compounds might easily cause a concentration of both copper and iron sulphates, and the copper sulphide, precipitating first, gradually increases the relative amount of iron until the chemical equilibrium would call for copper-iron sulphide instead of copper sulphide.

As further evidence that the deposit was a reconcentration of disseminated metallic salts, there are no igneous rocks within one hundred and twenty-five miles, neither are there any faults or fissures near

The " Red Beds " of Oklahoma are known to contain copper in a number of localities.[1] One of these which has been visited by the writer is near Coldwater, Okla. Here native copper occurs in the red shale in very thin sheets. The copper was probably reduced from the sulphate to the metal by the ferric iron in the shales. Haworth and Bennett[2] have ascribed such a possible origin to it. In this instance as well as in the one described above the copper has been concentrated by percolating waters. According to the geological column as worked out by Gould,[3] the deposit near Coldwater lies about 700 feet stratigraphically above the deposit in Payne County.

[1] Van Vleet, A. H., Second Bien. Rept. Dept. Geol. and Nat. Hist. Terr. of Okla., 1901–1902, p. 11.

[2] Haworth and Bennett, *Bull. Geol. Soc. Am.*, Vol. 12, pp. 2–4, 1900.

[3] Gould, C. N., " Water Supply and Irrigation Paper," No. 148, p. 23.

AN ALGONKIAN BASIN IN HUDSON BAY—A COMPARISON WITH THE LAKE SUPERIOR BASIN.

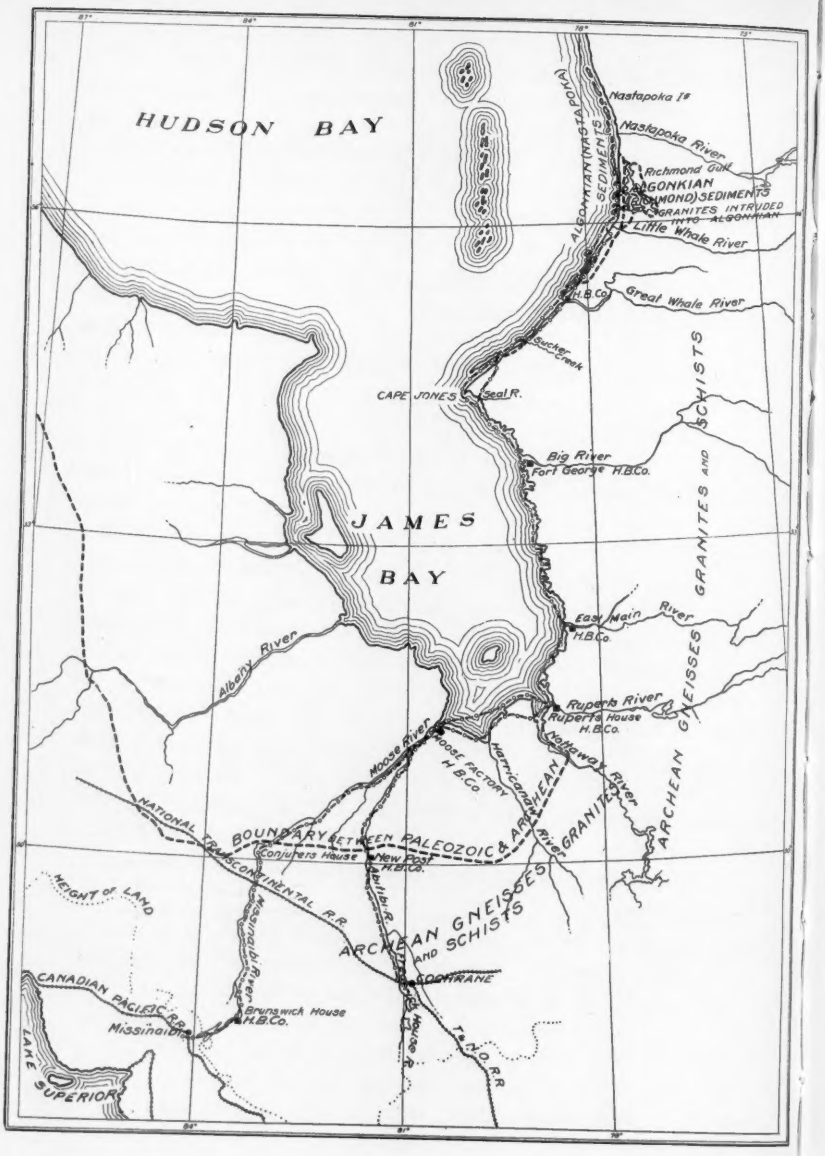
C. K. Leith.

During the summer of 1909 the writer made a section through the Canadian pre-Cambrian from the Canadian Pacific track at Missinaibi, Ont., down the Missinaibi and Moose rivers to Moose Bay, thence up the east coast of James and Hudson Bay to a point fifty miles north of Richmond Gulf. Returning along the east coast of Hudson and James bays, the return trip to the railroad was made up the Moose, Abitibi and Frederick House rivers to Cochrane, the junction of the Grand Trunk Pacific and the Temiskaming and Northern Ontario Railways. In this manner there were obtained two cross-sections of the interior pre-Cambrian shield and a view of the pre-Cambrian sediments of the Hudson Bay depression, well exposed along the east side of Hudson Bay, where vegetation is almost lacking. The short time available for travel and the rather arduous conditions of travel precluded detailed study in any one area. In this article the writer attempts to present certain features of his general comparison of the Lake Superior region with the interior and northern sides of the pre-Cambrian protaxis. All parts of the route traveled have been described by the geologists of the Geological Survey of Canada and the Ontario Bureau of Mines: Their reports, however, contain few general comparative observations.

Basins of the Moose, Missinaibi and Abitibi Rivers.

Bell, Robert. "Reports on the Geology of the Basin of Moose River and of the Lake of the Woods and Adjacent Country." Rept. of Progress for 1880–82, Geol. Survey Canada, 1883, pp. 1c–9c.

Parks, W. A. "The Nipissing-Algoma Boundary." Ont. Bur. Mines, Rept. 1899, pt. II., pp. 175–196.


HUDSON BAY
JAMES BAY
Nastapoka Is.
Nastapoka River
Richmond Gulf
ALGONKIAN (RICHMOND) SEDIMENTS
GRANITES INTRUDED INTO ALGONKIAN
ALGONKIAN (NASTAPOKA) SEDIMENTS
Little Whale River
H.B.Co.
Great Whale River
Sucker Creek
CAPE JONES
Seal R.
Big River
Fort George H.B.Co.
ARCHEAN GNEISSES AND SCHISTS
GRANITES
East Main River
H.B.Co.
Albany River
Rupert River
Rupert's House H.B.Co.
Moose River
Moose Factory H.B.Co.
Hannah Bay
Harricanaw River
NATIONAL TRANSCONTINENTAL R.R.
BOUNDARY BETWEEN PALEOZOIC & ARCHEAN
Conjuror's House
New Post H.B.Co.
Abitibi R.
HEIGHT OF LAND
Missinaibi River
ARCHEAN GNEISSES AND SCHISTS
COCHRANE
CANADIAN PACIFIC R.R.
Brunswick House H.B.Co.
Missinaibi
Moose R.
T. & N.O. R.R.
LAKE SUPERIOR

Bell, J. M. "Economic Resources of Moose River Basin (Ontario)." Ont. Bur. Mines, Rept. 1904, pt. 1, 1904, pp. 134–197.

McMillan, J. G. "Explorations in Abitibi (Ontario)." Ont. Bur. Mines, Rept. 1905, vol. 14, pt. 1, 1905, pp. 184–212.

Kerr, H. L. "Exploration in Mattagami Valley (Ontario)." Ont. Bur. Mines, Rept. 1906, vol. 15, pt. 1, 1906, pp. 116–135.

Henderson, Archibald. "Agricultural Resources of Mattagami (Ontario)." Ont. Bur. Mines, Rept. 1906, vol. 15, pt. 1, 1906, pp. 136–155.

East Coast of James and Hudson Bay.

Bell, Robert. "Report on an Exploration of the East Coast of Hudson Bay, 1877." Geol. Surv. Canada, Rept. of Progress, 1877–78, Montreal, 1879, pp. 1c–37c.

Low, A. P. "Report on Explorations in James Bay and Country East of Hudson Bay Drained by Big, Great Whale, and Clearwater Rivers." Ann. Rept. Geol. Survey Canada, vol. 3 (new ser.), pt. 2, 1888, pp. 1j–62j.

—— "Report on Explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Manicuagan and Portions of Other Rivers in 1892–93–94–95." Ann. Rept. Geol. Survey Canada, vol. 8 (new ser.), 1897, pp. 1L–311L.

—— "Report on a Traverse of the Northern Part of the Labrador Peninsula from Richmond Gulf to Ungava Bay." Ann. Rept. Geol. Survey Canada, vol 9 (new ser.), Rept. L, 1898, pp. 43.

—— "Report on an Exploration of the East Coast of Hudson Bay from Cape Wolstenholme to the South End of James Bay." Ann. Rept. Geol. Survey Can., vol. 13 (new ser.), Rept. D, 1903, pp. 84. (Published separately, 1902.)

—— "Report on the Geology and Physical Character of the

Nastapoka Islands, Hudson Bay." Ann. Rept. Geol. Surv. Can., vol. 13 (new ser.), Rept. DD, 1903, pp. 31.

SECTIONS ACROSS ARCHEAN PROTAXIS OF CANADA.

The rocks of the interior pre-Cambrian shield, where seen on the two cross-sections, belong entirely to the Laurentian and Keewatin series, as these terms are used in the Lake Superior region and defined by the International Geological Committee.[1] Dark green hornblende schists, mica schists, basalts, small masses of metamorphic slates, and other basic igneous rocks, together constitute the Keewatin. Granites and gneisses of the Laurentian occupy much larger areas than the Keewatin. Many instances of intrusive contacts of Laurentian into Keewatin were noted, yet there are considerable areas of both whose relations are not yet definitely established by observation. Some of the more metamorphic gneisses of the Laurentian are clearly older than their associated granites, and may be older even than part or all of the Keewatin. Both Keewatin and Laurentian rocks are dominantly schistose or banded, these structures being steeply inclined and striking generally north of east, a direction according with that of the dominant structures along the south side of the pre-Cambrian shield and in the Lake Superior region. No Huronian sediments, identifiable as such, were noted. The only sediments of any type seen were the highly metamorphosed slates closely associated with the Keewatin schists. Similar small masses of slates are rather common in the Keewatin on the south side of the pre-Cambrian shield. In reports of the Canadian and Ontario Surveys the dark green rocks, here collectively referred to the Keewatin, are frequently mapped as Huronian, this term having been there used, as in some other parts of Canada, in the old sense, to apply to green bedded and banded rocks in general, whether igneous or sedimentary.

The surface of the interior of the pre-Cambrian protaxis presents the peneplain features so well described by Wilson.[2]

[1] "Report of the Special Committee for the Lake Superior Region," *Jour. Geol.*, Vol. 13, 1905, p. 103.

[2] "The Laurentian Peneplain," by Alfred W. G. Wilson, *Jour. Geol.*, vol. 11, 1903, pp. 615–669.

PALEOZOIC ROCKS NEAR HUDSON BAY.

Toward Hudson Bay the Laurentian surface drops off rather abruptly into the Hudson Bay depression, occupied partly by Paleozoic sediments, which have been eroded to a lower level than the adjacent pre-Cambrian peneplain. The rivers coming out of the pre-Cambrian area, in approaching the Paleozoic area, plunge down in a series of rapids and falls through rather deep incisions in the pre-Cambrian rocks, furnishing the most striking scenery to be observed along the river courses. There is located, for instance, Conjurer's House, a great monolith of rock standing inaccessible in the midst of picturesque rapids, bounded by high cliffs, and regarded from time immemorial as an object of superstition by natives.

In the Paleozoic area bordering James Bay the rivers are wider, shallower, and less obstructed by rapids and falls.

The Paleozoic sediments dip gently toward Hudson Bay with minor folds, in the manner of coastal plain deposits. Highly fossiliferous limestone of Devonian age is conspicuous and abundant in the series. An interesting problem of sedimentation is furnished by the superposition of this limestone on the Archean rocks to the south of it with comparatively thin and locally absent beds of little-assorted red and ferruginous shale and grit and sandstone at their base. Parks[1] mentions one contact in which the corals of the limestone are seen standing upright on the old gneiss floor upon which they were deposited. Of further significance in regard to sedimentation is the presence in the Paleozoic of abundant gypsum, well exposed in the cliffs on both sides of the Moose River. It constitutes lens-shaped layers in the Paleozoic limestone. Local masses of iron carbonate are reported by Dr. J. M. Bell,[2] though not seen by the writer.

The Paleozoic rocks on the north side of the Archean protaxis contrast with those on the south side in having a larger proportion of limestone, in the presence of gypsum, in the ill-assorted and prevailing iron-stained character of the fragmental sediments

[1] Ont. Bur. Mines, vol. 8, pt. II., 1899, p. 188.
[2] Ont. Bur. Mines, vol. 13, pt. I., 1904, pp. 150–152.

beneath the limestone, and in the small quantity of these sediments.

GLACIAL DEPOSITS.

Glacial deposits overlie the region. The coastal plain area of Paleozoic rocks bordering the Bay exhibit thick stratified clays with interbedded lignites. The lignite beds are thin, probably too thin to be utilized. Post-glacial marls, silts and muds, usually well cemented, containing marine shells like those of species now living in the waters of James Bay, overlie the glacial deposits of the Paleozoic area and lap against the pre-Cambrian rocks to the south, there forming well-marked sea beaches. Since glacial times the sea has evidently covered all of the region as far south as the pre-Cambrian boundary. The recession of this sea is perhaps still going on, though the positive evidences of this which have been cited by geologists who have studied the region have been questioned by others.

ALGONKIAN ROCKS ON EAST COAST OF HUDSON BAY.

The east shore of James Bay from Ruperts House to Whale River is occupied by Laurentian and Keewatin rocks, principally the former.

North of Cape Jones in Hudson Bay appear the first pre-Cambrian sediments of probable Algonkian age, which are seen crossing the protaxis from the south. These sediments were described in 1878 by Bell;[1] later and more fully by Low.[2]

In their early reports Bell and Low referred these sediments to the Cambrian; later Low regarded them as of Laurentian age. No local names seem to have been used for them. As the writer does not regard them as either Cambrian or Laurentian, he is compelled to use local geographic names for these sediments. The sediments typically exposed on the Nastapoka islands and adjacent mainland will be here called the Nastapoka group. Another group of sediments, unconformably below, although only slightly discordant in structure, typically exposed on Richmond Gulf, will be here called the Richmond group.

[1] *Op. cit.*
[2] *Op. cit.*

The Nastapoka and Richmond group lie in the Hudson Bay depression with approximately similar structural and topographic relations to the Archean protaxis as are exhibited by the Paleozoic rocks of the south side of the Bay.

The Nastapoka group is first seen by the northbound traveler on Long Island, just north of Cape Jones (separating James and Hudson Bays), and along the shore in isolated patches as far as Great Whale River. From Great Whale River north it makes up the islands and a narrow strip along the shore, almost continuously to near Portland Promontory, a distance of about 350 miles from Cape Jones.

The Nastapoka group is a little metamorphosed series of mechanical and chemical sediments, interbedded with basic eruptives, dipping seaward at angles varying from 5° to 45°.

The Richmond group is exposed on Richmond Gulf and on the adjacent mainland north and south. It consists of coarse, ill-assorted mechanical sediments, interbedded with basic eruptives, dipping in general seaward at angles only slightly greater than the dips of the Nastapoka group. It is therefore exposed in general in the band between the Nastapoka group on the west and the old Archean protaxis on the east, upon which the Richmond group lies unconformably, as does also the Nastapoka group in the area farther north and south, where the Richmond group is absent.

The Nastapoka and Richmond groups are of special interest to a student of Lake Superior geology in their similarity of lithology and structure to certain Huronian sediments of the Lake Superior basin, in content of iron formation identical with that of the Huronian of the Lake Superior basin, and in relations to vulcanism. The rocks are nearly bare of vegetation, affording excellent sections for study of conditions of pre-Cambrian sedimentation. Both groups form conspicuous monoclinal ridges reaching elevations of 350 feet on the Nastapoka islands and 1500 feet in Richmond Gulf. The gently dipping strata, eroded in regular castellated forms, rise in steep and regular step scarps from the water, the bright and contrasting colors of the strata softened and

buried by the subarctic mosses and shrubs, all standing out from the brilliantly clear, sparkling blue waters of Hudson Bay.

The general succession for the Nastapoka region below given is essentially taken from Low,[1] though modified by the writer's observations in manner later to be noted. In the main Low's excellent observations were verified.

PRE-CAMBRIAN SUCCESSION IN NASTAPOKA ISLANDS, RICHMOND GULF, AND VICINITY.

Nastapoka Group.

The order is descending:

1. The sediments of the Nastapoka Islands, consisting from the top down, quoting from Low, of:

(*a*) Rusty weathering, dark gray, siliceous rock containing ankerite (carbonate of iron and magnesia) and magnetite,	20–100
(*b*) Dark-gray siliceous rock containing magnetite with small quantities of ankerite,	50–250
(*c*) Red jaspilyte rich in hematite ore,	10–100
(*d*) Red jaspilyte poor in hematite ore,	5– 20
(*e*) Purple, or greenish-weathering, dark-green, graywacke shales,	10– 70
(*f*) Red jaspilyte poor in hematite ore,	0– 5
(*g*) Light greenish-gray sandstone and shale,	10–300
(*h*) Fine grained dolomite	0– 50

2. A great basaltic trap showing basaltic parting, ellipsoidal or pillow structure, amygdaloidal and other surface textures, with thin and discontinuous interbedded red sandstone, occupying the shore to the east of the Nastapoka Islands, and southward forming the capping of Manitounuk Islands. 400 feet thick.
3. Sandstone and quartzite with layers of limestone and shale near the top, especially well exposed on the Manitounuk islands. Maximum of 900 feet.
4. Limestone and dolomite, showing variations in lithology in different bands, the greater mass being characterized by a

[1] Ann. Rept. Geol. Surv. Can., vol. 13 (new ser.), Rept. DD, 1903, p. 9.

coarse concretionary structure. Locally, at Little Whale River and elsewhere, contains beds of sandstone. Exposed principally on east side of Manitounuk Sound, and Long Island, and shore west of Great Whale River, and on the eastward facing scarps along the west side of Richmond Gulf. Rests unconformably on granite where Richmond Group is absent.

Unconformity, marked by slight bevelling of the underlying series.

Richmond Group.

5. Coarse arkose grading above into sandstones and argillites. Interbedded with basic flows, 1,000 feet. Intruded by some of the red granites of the mainland against which the Nastapoka series lies. Exposed along the lower parts of the eastward facing scarps along the west side of Richmond Gulf, forming most of the islands and eastern shores of Richmond Gulf. Low estimates 2,450 feet.

Unconformity.

Archean (Laurentian).

6. Granite and gneiss.

Low does not recognize an erosion unconformity within the sediments. He regards member no. 1, the Nastapoka group, as equivalent to the red sandstones and argillites just above the Richmond arkose, no. 5 of this section, their present relations being thought to be due to thrust faulting along the plane of unconformity between no. 4 and no. 5, bringing up the iron formation member again. The interpretation of this structural discordance between no. 4 and no. 5 as thrust faulting rather than erosion interval the writer could not agree to. While some slipping along this plane has unquestionably taken place, the distribution of the rocks above and below does not accord with a fault hypothesis. The underlying Richmond rocks are bevelled. The lowermost of the overlying Nastapoka beds is a continuous even member, always showing the same relation to the plane of structural discordance. There is no thickening or thinning of the upper beds in relation to this plane of discordance which would

be required by faulting. Also the difference in lithology and in minor folding and faulting between the two groups, so close together areally, seems to the writer to preclude the probability of their being equivalent in age. Neither the contact plane nor the upper group seemed to show deformation or shearing which might be expected from the overthrust of such magnitude as fault interpretation would require. Finally the lowest member of the Nastapoka group rests unconformably on granite, where the Richmond group is absent, along over 100 miles of coast extending east and north from Cape Jones.

The section above given differs from Low's also in classing part of the gneisses and granites forming the mainland, as a basement, unconformably below the sediments. Low describes them everywhere intrusive into the arkose no. 5 of the series. The contacts along the east and south sides of Richmond Gulf, specifically described by Low as showing intrusive relations, were examined, and though the evidence is not everywhere conclusive, it seems probable to the writer that the granites are there intrusive into the arkose member no. 5. However, in addition to the intrusive red granites, there are certain basic, more gneissic, granites exposed on the south shore of Richmond Gulf, and particularly forming the part of the mainland south of Richmond Gulf and southwest of Great Whale River. Contacts of these rocks with the Nastapoka group are clearly those of erosion unconformity. In walking along the shore between Great Whale River and Sucker Creek, a distance of forty miles, some twenty actual contacts were noted of fragmental conglomerate at the base of Nastapoka limestone upon the old granite and gneiss, and filling cracks and other irregularities in its surface. No unconformable contact of the older gneissic granite with the Richmond group was seen by the writer, nor is any described by Low. It seems to the writer probable that the so-called Laurentian here, as this term is used by Low to cover all the granites and gneisses, really consists, as in many other places in Canada, of igneous rocks of two ages, one older than the adjacent Huronian sediments, the other later and intrusive into the Huronian sediments.

Whether the intrusive granite here is also intrusive into the Nastapoka group, no evidence is yet available to show.

IRON FORMATION.

The iron formation exposed in the Nastapoka Islands is of special interest because of its remarkable lithological similarity to the iron formation of the Upper Huronian or Animikie group of the Lake Superior region. All phases, both altered and original, of the Animikie iron formation are here represented, with one exception. The altered phases are the jaspers, ferruginous cherts and ores; the original phases are the iron carbonates. Unaltered greenalite rock was not seen, but the lower part of the iron formation seems originally to have consisted largely of greenalite, giving, when altered, the peculiar spotted ferruginous chert or taconite, with granule forms so characteristic of the greenalite, or taconite in the Mesabi district of Minnesota. The upper part of the Nastapoka iron formation consists principally of ferruginous cherts and jaspers of a more regularly banded type, similar to those resulting from the alteration of iron carbonate in the Gogebic and Marquette districts of Michigan. Much original iron carbonate remains. The relatively greater abundance of residual unaltered carbonate than of greenalite has been noted in the Lake Superior region, where these proportions seem to have genetic significance.[1] The depressions on the dip slopes of the iron formation, where the overlying ferrodolomite has been stripped off, contain concentration to iron ore. No large iron ore deposits of good grade are exposed. On the scarp slopes an occasional band not exceeding four feet in thickness is sufficiently rich in iron to reach commercial grade. Glacial erosion has been deep on the Nastapoka islands, as it has on the mainland, and it seems to be reasonably certain that any further concentrations of iron ore which may be supposed to have been present before glacial time have been largely swept away by the glacial erosion, for the ores are softer than the adjacent rocks. To what extent this erosion has

[1] "Geology of the Lake Superior Region," by C. R. Van Hise and C. K. Leith. Monograph U. S. Geological Survey. (In press.)

removed ore deposits on the dip slopes under the waters of the bay is not apparent.

CONDITIONS OF SEDIMENTATION OF PRE-CAMBRIAN SEDIMENTS.

A study of the Nastapoka and Richmond groups seems to the writer to afford a more satisfactory basis for interpretation of the conditions of sedimentation of pre-Cambrian sediments than is available in almost any other section of the great pre-Cambrian shield, because the record here presented is not obscured by glacial drift or vegetation. Without going into all details of evidence, the facts are taken to afford a reasonable basis for the following hypothesis concerning the origin of the Nastapoka and Richmond groups.

An old land area situated to the east and south of these groups, much like that there found now, yielded to the rivers a great mass of coarse arkose, which was deposited in low tideswept fans at their mouths. Specifically arkose beds were thus formed in the great area centered in Richmond Gulf, making up the Richmond arkose (no. 5 of the section). It does not seem unlikely that the great mass of arkose in Richmond Gulf may be the deposit of a single large river, more or less worked over by the tides and currents along the shore. The waters along the east coast of Hudson Bay today are depositing material of identically the same lithological characteristics, and in masses of similar order of magnitude. Indeed, the identity of the work now being done with that done when the arkose of the Nastapoka series was deposited cannot but suggest similarity in climatic conditions.

Toward the later part of this period of arkose deposition there were volcanic outbreaks bringing in sheets of lava. These were poured out approximately along the shores and tidal flats, for the coarse sediments immediately below and above them exhibit the wide variety of ripple and current marks duplicated in the tide flats of the shore today. Also the flows themselves show not only basaltic, amygdaloidal and scoriaceous textures resulting

from surface cooling, but the peculiar ellipsoidal or pillow parting, often ascribed to subaqueous cooling, indicating substantially shore or shallow water conditions.

Accompanying and following these volcanic disturbances the group was slightly tilted, flexed and faulted. Erosion bevelled the series, but it seems likely that much of the erosion may have been contemporaneous with the deposition of the group, as it is today, for instance, along Great Whale River, where coarse arkose with a marked initial dip is being deposited by the rivers, and where parts of the deposit now above water are being bevelled by wind erosion and by the waves during severe storms and unusually high tides. If today the waters of the bay should advance over these recent arkose deposits of Great Whale River they would deposit sediments upon the arkose with discordance similar to that noted at the top of the arkose member of the Nastapoka series. Yet the time interval represented might be short.

Change of conditions, perhaps partly consequent upon vulcanism, brought about the deposition of thinly bedded limestone and layers of sand (no. 4), grading up into sandstone and quartzite (no. 3), upon the eroded edges of the arkose. It seems likely that this change consisted in deepening of the water, for the deposition of coarse arkose was suddenly stopped and deposits ordinarily ascribed to quieter, deeper water conditions were formed. The limestones show much less of the ripple marks and other shallow water evidences than is shown by the arkose below. This might mean that the area had been suddenly inundated, bringing deep water over the arkose and perhaps transferring the zone of arkose sedimentation further inland. That the change was probably somewhat rapid is shown by the absence of any considerable fragmental material at the base of the limestone series, although there are present a little coarse conglomerate and coarse arkose. A shallowing of the waters, perhaps due to the building up of the limestone, perhaps due to a recession following the sudden encroach of the water indicated by the deposition of the limestone, brought about shallow water conditions and the deposition of thinly bedded quart-

zites no. 3, showing conspicuous evidences of shallow water conditions.

At the same time deposition of limestone may be presumed to have continued farther from shore. The limestone beneath the iron formation on the Nastapoka islands (no. 4) may be substantially contemporaneous with the deposition of the limestone *and* quartzite farther inland.

Then came the great outburst of vulcanism, much greater than that in the arkose time, depositing no. 2 of the section—surface basalts giving evidence by the thinly banded ripple-marked sediments above and below and between them, and by their own combination of ellipsoidal with basaltic, amygdaloidal and scoriaceous textures, of extrusion at or near water level, not improbably along tidal flats. This was accompanied by extrusion of fragmental volcanic material, mud, ashes and tuffs, now preserved principally in the off-shore area near the base of the iron series on Nastapoka islands. The limestone floor here had an irregular hummocky surface upon which, with remarkable abruptness, appear the dark green volcanic muds and ashes, interbedded with thin seams of graywacke and channel-like runs of quartzite, ripple-marked and current bedded, indicative of rapid currents and sudden changes. It may not be that their deposition involved any change in depth of water; a sudden contribution to the waters of large quantities of mud which the disturbed waters were not able to distribute would accomplish the result. The limestone floor has great concretionary structures up to two feet in diameter, the lines of the concretions locally open on one side, and locally opening out into waved and crenulated bedding lines, interpretation of which the writer does not attempt, but which probably tell of conditions which if known would indicate the depth of water and perhaps other significant conditions of their formation.

After twelve or fifteen feet of this dark green mud had been deposited, the sediments became somewhat more assorted, into layers of green mud, graywacke, gray, green and white quartzite, carbonate slates, and iron carbonate. The chemical and miner-

alogical composition of the volcanic mud[1] is about such that if distributed by currents it might well yield a combination of sediments like that appearing above the mud at the present time. Diminishing of the quantity of mud enabled the waters to work it over and distribute it to some extent.

Iron carbonate and greenalite, now represented principally by the more varied oxidized phases of the iron formation, were next deposited. Then came ferro-dolomites and limestones, suggesting a rather rapid diminution in the contribution of iron salts and return to the older conditions of limestone deposition which had been interrupted by the volcanic outburst.

GENETIC RELATION OF IRON FORMATION AND VOLCANICS IN NASTAPOKA GROUP.

The association of iron formation and volcanics and the manner in which the iron formation grades into the carbonate slates and other little assorted sediments following the sudden volcanic outburst cannot fail to suggest that its deposition is in some way related to the volcanic extrusion. Similarly, the fragmental sediments immediately below *and* above the basalts of the Richmond group are without exception heavily iron-stained, so much so in fact that some of them might be called impure jaspers, although they are still essentially fragmental rocks. Low refers to them as jaspilites. That typical iron formations free from fragmental sediment were not deposited in the lower or Richmond group, may be explained by the supposition that even if iron salts were as abundant as later in Nastapoka time (which is not a necessary assumption), at this particular time and place there was a large amount of fragmental material which had to be handled and which went down with the iron salts and prevented their accumulation in pure form.

In Hudson Bay, as in the Lake Superior region, iron formations have been deposited only at times of volcanic activity. None formed in the Paleozoic, or at present, in absence of vulcanism.

[1] "The Source of the Upper Huronian Group of Sediments of the Lake Superior Region," by S. H. Davis. A thesis submitted for the degree of bachelor of science, University of Wisconsin, 1909.

Evidence connecting the iron formation deposition with the volcanic extrusions is to be observed in the lavas themselves and in the sediments of the Richmond group, which contains interstratified basalts. The basalts are all characterized by an abundance of jasper veins, jasper filling of amygdules, jasper cements between the blocks of ellopsoidally parted flows. Striking indeed is the brightly colored jasper cement outlining the pillow forms on many of the beautifully exposed glaciated surfaces. These cements show complete gradation from ordinary ferruginous cherts into various phases of the basalt itself. When examined for the purpose of determining whether they were the result of late secondary replacement of ellipsoidal basalt or more nearly primary in their origin, developing in the hot lava or during cooling of the lava, there could be no reasonable doubt that the work was accomplished by solutions working in the basalt before it was subjected to surface alterations, certainly under conditions differing radically from those of ordinary weathering as observed today. The intimate relation of the jasper veins and cements with the fresh basalt itself would seem to show nearly a contemporaneous crystallization in part. Today no jasper cements are being deposited in the blocks or fissures or amygdules. Cold weathering of the lavas gives little evidence of the gathering of iron which would yield these jasper cements. If these jasper veins and cements were introduced by weathering solutions, there would need to be explained the complete absence of weathering along their contact with the basalt. In short, the evidence is here abundant and conspicuous, of the kind which has already been found, though less conspicuously, for the Lake Superior region, that one of the late accompaniments of the extrusion of the surface igneous rocks and especially those with the ellipsoidal structure, were abundant iron-bearing solutions.

The obvious abundance of iron solutions available during the extrusion of the igneous rocks, the appearance of iron formations and other highly ferruginous rocks in the Nastapoka and Richmond groups only accompanying and following the volcanic extrusions, when normal conditions of sedimentation such as may be observed today had been suddenly and radically

changed, presumably under the influence of vulcanism or under the influences which also caused vulcanism, seem to the writer to favor the hypothesis that the essential requisite for the deposition of the iron formation—the variant in the normal conditions of non-iron-bearing sedimentation—was the event of great masses of basic lavas carrying excess of iron salts, contributing the iron salts in unusual amounts to the shallow waters, which disposed of them as best they could while handling the ordinary fragmental and chemical sediments resulting from erosion of the adjacent shore, sorting them well where the amounts allow it, sorting them not at all at first when the mass of material offered is too great for the waters to handle.

The specific processes of derivation of the iron carbonates or greenalite, making up the original iron formation from the igneous rocks are not known—whether they result from working over of volcanic fragmental material, or from direct contribution of iron salts in hot solutions from the lavas extruded with the volcanic fragmentals; whether they result from the reaction of atmospheric agents on the hot lavas, giving unusual amounts of iron solutions to the waters; whether they result from ordinary weathering, under normal atmospheric conditions, of extensive lava beds then forming the main part of the adjacent shore; whether they represent some combination of these processes. These various hypotheses are discussed in connection with the origin of similar iron formations of Lake Superior region in a monograph on that region, now in press. It is the purpose here merely to call attention to the close association of iron formation in this region with volcanic extrusion, to intimate its probable genetic connection, and to note the remarkable accordance of the evidence for this genetic connection here with that more fully developed for the Lake Superior region.[1]

CORRELATION.

The Nastapoka and Richmond groups are separated from the nearest Algonkian sediments on the south side of the pre-Cam-

[1] "Geology of the Lake Superior Region," by C. R. Van Hise and C. K. Leith. Monograph U. S. Geological Survey. In press.

brian shield of Canada by 500 miles of pre-Cambrian rocks (mainly Laurentian and Keewatin), and correlation therefore becomes a doubtful matter. That the Nastapoka and Richmond groups are pre-Cambrian seems to be reasonably probable from their apparent lack of fossils and in their remarkable contrast, not only in this regard, but in lithology, with well identified Paleozoic sediments on the south side of James Bay. They are also somewhat more deformed and metamorphosed than the known Paleozoic, and, like the pre-Cambrian of the Lake Superior region, are associated with volcanic rocks, which the Cambrian lack, unless it be assumed that the Keweenawan is Cambrian, which the writer does not. The slight metamorphism and folding of the Nastapoka and Richmond groups suggests comparison with the late pre-Cambrian, such as the Animikie or Keweenawan, of the Lake Superior region, rather than with the earlier Huronian. More specifically, in metamorphism and folding, in possession of an iron formation containing both iron carbonate and derivatives of greenalite granules, in relations of iron formation to vulcanism, the Nastapoka group presents similarities to the Animikie, or upper Huronian, of the Lake Superior region. Low,[1] in his report on the Nastapoka group, has pointed out this similarity, and when visiting the Mesabi district with the writer frequently referred to the identity in lithology of the Nastapoka iron formation with that of the Biwabik formation of the Animikie group of the Mesabi district, an identity with which the writer fully agrees.

The break between the Richmond and Nastapoka groups is much slighter than that between the middle and upper Huronian of the south side of the Archean protaxis. It may rather correspond to the slight break within the Animikie at the base of the iron formation of the Mesabi and Gogebic districts.

Bell and Low, in their early reports,[2] refer the Nastapoka sediments to the Cambrian. In later studies in the interior of Ungava, Low reports the finding of similar rocks grading into highly metamorphosed phases where intruded by granites.

[1] *Op. cit.*, pp. 10–11.
[2] *Op. cit.*

These metamorphic phases he says are similar to the Grenville limestones of Lower Ontario, which are intruded by Laurentian granites. He therefore classes the Nastapoka and equivalent sediments as Laurentian and regards them as perhaps the oldest known pre-Cambrian sediments, notwithstanding their lack of metamorphism and deformation where exposed along the Hudson Bay shore.[1] If the sediments had been first studied in their metamorphosed portion and been classed as Laurentian, the same kind of argument would have warranted Low, when he found the unaltered portion, in classing them as late Huronian. This but illustrates the difficulty of correlation.

While, therefore, a satisfactory correlation, in the nature of the case, is impossible, one familiar with Lake Superior geology is tempted to regard the Nastapoka series as of Animikean age. Whether or not it is Animikean is a matter of small import; much more significant is the fact that on the north side of the Archean protaxis—a protaxis which at least in its central portion appears to have no Algonkian sediments, though more exploration is necessary to establish this—there appear late Algonkian sediments similar to those bordering the southern side of the protaxis, as well represented in the Lake Superior region.

Whether these sediments once extended all over the pre-Cambrian protaxis of Canada and have since been removed by erosion from the central part it is not possible to demonstrate, though it seems improbable. With the remarkably low dip of the late Algonkian sediments both north and south, some patches should be expected to be found in the Archean protaxis if deposition there occurred.

The Lake Superior region was in pre-Cambrian times part of a general geosyncline of deposition with its axis running east and northeast from the Lake Superior region through the Huronian areas of eastern and southern Ontario including the Cobalt and Larder Lake areas. To the north of this geosyncline was apparently a land area of Archean rocks against which successive Algonkian seas worked from the South. The pres-

[1] Ann. Rept. Geol. Survey Canada for 1900, vol. 13, 1903, Rept. DD, pp. 15–16.

ence of similar sediments in the Hudson Bay depression on the north side of this protaxis suggests the further generalization that here was another geosyncline of deposition. These generalizations in their very nature can be of the most tentative type, and the writer should be acquitted of any attempt to intimate that they are established. They are presented merely as a working hypothesis to explain facts known to date, and to direct further observations on correlation.

From an economic standpoint the repetition of essentially Lake Superior conditions in the Hudson Bay country cannot but be of interest, whether these were originally separated geosynclines of sedimentation or whether they were originally connected, when it is remembered that the enormous deposits of iron, copper, nickel and cobalt on the south side of the Archean protaxis are, with very few exceptions, associated with Algonkian rocks, and late Algonkian at that, rather than with Archean rocks. There are yet no discoveries to warrant close commercial comparison of the two regions.

THE COPPER-BEARING AMYGDALOIDS OF THE WHITE RIVER REGION, ALASKA.[1]

ADOLPH KNOPF.

GENERAL GEOLOGIC FEATURES.

The region to be considered embraces the headwater drainage area of White River, a large tributary emptying into the Yukon seventy miles above Dawson. The area adjoins the International Boundary between Alaska and Canada (the 141st meridian) and is situated approximately in latitude 62° north.

The rocks underlying the region are mainly of Carboniferous age.[2] Lithologically they include shales, sandstones, limestones and volcanic rocks of basaltic composition. The volcanics comprise a stratiform succession of amygdaloids, porphyritic sheets, tuffs and breccias, several thousand feet thick, and in places they form the dominant portion of the Carboniferous formation. Petrographically the volcanics prove to be plagioclase-augite rocks in a more or less altered condition. As the tuffs and breccias are locally fossiliferous and interleave with ordinary clastic sediments, it is probable that the volcanics were in the main accumulated under submarine conditions.

A few intrusive masses of diorite are known to invade the rocks of the region, and in the area lying just to the north have produced some bodies of contact-metamorphic copper ores in the intruded limestone.

The youngest rocks are Tertiary lavas, largely hypersthene andesites and basalts, emitted from the volcanic vents of the Wrangell Mountains. They attain their maximum thickness among the castellated summits of the mountains at the head of White River.

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] The field work on which this paper is based was done in collaboration with Mr. F. H. Moffit; Moffit, F. H., and Knopf, Adolph, "The Mineral Resources of the Nabesna-White River region, Alaska," Bull. U. S. Geol. Survey No. 417 (in press).

MODE OF OCCURRENCE.

The probable occurrence of native copper in the region has long been surmised from the reports of the Indians. The upper White River country was first penetrated by white men in 1891, when an exploring party, consisting of three men, one of whom was Dr. C. W. Hayes of the U. S. Geological Survey,[1] crossed Skolai Pass at the head of White River and made its way to the coast by way of the Copper River drainage. At that time astonishing Indian accounts concerning the enormous quantities of native copper that might be found in the region were told to the members of the expedition while at Fort Selkirk, on the head of the Yukon. It was reported that copper nuggets up to the size of a log cabin might be discovered. During the trip up White River and over the glacier-filled Skolai Pass, which was made by back-packing and which consequently allowed only a casual examination of the line of travel, little was seen that countenanced the exaggerated statements of the Indians. It was definitely ascertained, however, that some placer copper was present in the stream gravels of Kletsan Creek, near the international boundary. The first published description of copper as a prospective resource of the region was given by Brooks,[2] who, as geologist accompanying the Peters exploring expedition of 1899, came to the conclusion from the abundance of copper indications "that this upper region is one that is worthy of careful investigation by the prospector and the capitalist."

In 1902 a placer gold stampede brought an influx of prospectors into the upper White River country, but as no paying quantity of precious metal was discovered the majority soon left for more promising fields. The few who stayed turned their attention to the copper resources of the region, being in many cases incited to this search by the prevalent Indian reports of large deposits of metallic copper.

Copper occurs native as nuggets in the gravels of many of

[1] Hayes, C. W., "An Expedition Through the Yukon District," *Nat. Geog. Mag.*, 1892, pp. 117–162.

[2] 21st Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 382.

the streams, and green-coated lumps of metal up to five pounds or more in weight are occasionally found in the wash of creeks draining areas of amygdaloid bed rock. This stream copper, dug out by crude implements made of caribou horn, was the source from which the Indians obtained their supply when it was an object of barter among them. From the accounts of Hayes and Brooks Kletsan Creek appears to have been the placer locality best known to the natives.

Metallic copper occurs also in the surface croppings of some sulphide deposits in the amygdaloids, where it is undoubtedly an oxidation product of the sulphides that appear in depth. In such cases it is directly associated with the dark-red oxide (cuprite) and more or less green carbonate. At the prospect known as "Discovery," which is located in Canadian territory on White River a few miles below the international boundary, a large slab of native copper averaging 8 by 4 feet by 4 inches thick and weighing probably close to 6,000 pounds, has been uncovered in the slide rock. A number of other sheets of copper up to several hundred pounds in weight have been found in the near vicinity. This find has exerted a great stimulus on the prospecting of the adjacent American territory. Stripping of the bed rock near the great nugget exposes a face of green basalt-amygdaloid 20 feet high and 15 feet wide, which is traversed by numerous seams of native copper along fractures and slickensides. Toward the bottom of the open cut stringers of chalcocite begin to appear. One hundred and fifty feet from this prospect an opening on another, but independent, occurrence shows stringers of glance and calcite and chalcopyrite disseminated through the amygdaloid country rock. From these features it is probable that the metallic copper of this deposit is a superficial oxidation product of sulphides; that its downward extension is small; and that the prevailing sulphide at greater depth will probably turn out to be chalcopyrite.

This deposit is about 35 miles from those to be described on the head of White River.

On Moraine Creek, a small stream in a glacier-filled valley on

the east side of Russell Glacier, the great ice-stream occupying the pass at the head of White River, a number of claims were staked during 1907 and 1908. The bed rock here consists of green and reddish amygdaloids with associated breccias striking N. 85° W. (magnetic) and dipping 55° S. At some places it can be seen that the upper portions of individual lava flows are more highly amygdaloidal than the rest of the sheet. Malachite-stained fragments of rock can readily be found in the talus slopes. Copper occurs in place in small seams cutting the amygdaloid, the veinlets consisting of finely developed spherules of prehnite intergrown with calcite and flecked with red metal and chalcocite. Examined in thin section small clean grains of copper are found embedded in both prehnite and calcite; some chalcocite occurs similarly. A small amount of native copper is associated with a little iron hydrate, and this copper may have been derived from the reduction of chalcocite.

Traversing the amygdaloids there are also small drusy stringers composed of quartz and prehnite and containing chalcocite and a black combustible mineral of lacquer-like appearance which, when ignited, burns with a smoky yellow flame. At another point on Moraine Creek the lava, in addition to containing white amygdules of zeolite, carries irregular blebs of chalcocite which give the rock somewhat the appearance of a glance-bearing amygdaloid. Such development work as has been done on Moraine Creek indicates that the amygdaloidal phases of the basalts are the most favorable and that these are most likely to be found along the contacts of successive lava flows. As the superimposed sheets of lava commonly differ in color and texture, the contacts can easily be located.

On the west side of the head of White River the same Carboniferous volcanics form the wall of the valley. They consist of basaltic tuffs, breccias, amygdaloids, and porphyritic sheets, dipping 10° toward the north. The colors of the lavas are dark red-browns and greens. A number of prospects have been located on chalcocite croppings a few miles below the edge of the moraine of Russell Glacier. In the main these outcrops consist

of small bodies of shattered amygdaloid reticulated with seams of chalcocite. At one prospect there is exposed a thin glance stringer an inch or so in thickness, cutting vertically across the nearly horizontal volcanics. It is adjoined by sheared amygdaloid walls, and veinlets of white earthy material ramify through the adjacent rock to considerable distances. A few hundred feet below this, on what is thought to be the same vein, is another open cut on a glance stringer about 3 inches wide, largely solid sulphide, which is intergrown to some extent with a zeolite mineral of a specific gravity of 2.27, probably laumontite. The cliff above the cutting shows that the stringer pinches out vertically within 6 feet.

At the head of the Middle Fork of White River, a large tributary entering the main stream five miles below Russell Glacier, some claims have been staked on outcrops of rock carrying native copper. Two small open cuts 1,450 feet above the stream were seen on the Copper King claim. The country rock at this locality consists of stratiform basalts intercalcated with beds of breccia and brick-red tuffs, striking N. 65° W. and dipping 18° south into the mountain. On the talus slopes can be found fragments of amygdaloid containing fine radial groups of thomsonite and fragments of amygdaloid permeated with minute seams of the combustible mineral previously noted on Moraine Creek. Native copper is apparently limited in its occurrence to a certain definite volcanic sheet—a reddish lava, which is in places highly amygdaloidal. Overlying this is a stratum of coarse pyroclastic, which in turn is capped by a massive flow of basalt, a notable cliff-maker. In the breccia occur fragments of amygdaloid, proving that the filling of the vacuoles took place during the time elapsing between successive extrusions of lava. For 200 feet along the outcrop of the amygdaloidal sheet metallic copper intergrown with prehnite, calcite, and zeolites can be found here and there in encouraging amounts. The prehnite occurs in characteristic globular groups made up of minute rectangular plates. The thickness of the cupriferous portion of the amygdaloid appears to be about 6 feet, but as almost no development

work has been done on the property, figures of this kind have little value. The copper occurs as irregular reticulating masses of metal several inches long and as small lumps and minute particles embedded in the minerals that fill or line the former vesicles in the lava flow. In places these minerals ramify in the shape of small veinlets through the body of the rock surrounding the amygdules or form irregular masses, and such places are eminently favorable for metallic copper. In appearance the ore is strikingly like that of the amygdaloid ore of the Lake Superior country.

This occurrence is the only one in the region in which the native copper appears to be of undoubted primary origin. If the ore shown on the surface has any downward extension, it can be predicted with a high degree of confidence that metallic copper will also persist downward. To this extent the surface indications are distinctly favorable. Some doubt, however, as to the probable amount of ore may perhaps be entertained in view of the character of the deposit. It is well known that occurrences of native copper associated with zeolites filling amygdules in basaltic lavas are found throughout the world in widely separated localities—the Faroe Islands, the trans-Baikal region, Brazil, Queensland, New Guinea and Lake Superior—but only the Lake Superior region has so far yielded bodies of commercial ore.

From the southern side of the Wrangell Mountains, in Chitistone River, about thirty miles from the head of White River, Moffit has described[1] cupriferous amygdaloid which is analogous to the White River occurrences. This sheet is a member of a great series of pre-Triassic bedded basalts, possibly aggregating 4,000 feet in thickness, which is undoubtedly the extension of the volcanic series of the White River region. The vacuoles of the amygdaloid are filled with a black coaly mineral and in places contain considerable metallic copper. Furthermore, the combustible mineral contains disseminated through it, in a form not visible to the eye, perhaps as a solid solution, some copper compound soluble in HCl, which is possibly cuprous oxide.

[1] Bull. U. S. Geol. Survey, No. 345, 1908, p. 168.

THE GENETIC PROBLEM.

Some suggestions may be advanced as to the origin of these copper occurrences. The following features must be taken into account: That chalcocite and zeolites occur together in certain deposits; that native copper and zeolites occur in others, and that in a third type both chalcocite and native copper are associated together in a gangue of zeolites. Obviously all three of these modes of occurrence represent slightly differing aspects of the same mineralization.

The close association of the copper-bearing minerals with the zeolitic filling of the amygdaloids proves that all have a common origin. Any theory accounting satisfactorily for the zeolites will also account for the copper. It is well known that zeolites may be formed in a variety of ways: (1) At a temperature near 0° C. in the abysmal oceanic depths, (2) by ordinary cold surface waters, and (3) by ascending thermal waters.

Van Hise[1] states that "it may be that zeolitization combined with other alterations furnishes sufficient material to entirely fill the vacuoles of many amygdaloids without material being furnished from an extraneous source." He believes, however, that much of the zeolite material is derived from the belt of weathering. Mathematically he shows that the hydration, carbonation and oxidation of an amphibole gabbro in the belt of cementation would produce an increase of 25.21 per cent. in volume. An expansion of volume of this character and amount would be sufficient to supply the quartz, zeolites, chlorites, epidote, serpentines and carbonates filling the amygdules in amygdaloids.[2]

Geologically, however, the process of zeolitization seems sometimes to take place in a more complex fashion than postulated in the above reactions. For instance, the occurrence of the zeolite harmotome containing 20 per cent. BaO as a filling in amygdaloidal basalts, whose content of BaO ranges from a trace to only 0.11 per cent., implies an exceedingly large ratio of concentration. Brewsterite contains from 9 to 10 per cent. SrO, and

[1] Mon. U. S. G. S., No. 47, p. 333.
[2] *Op. cit.*, p. 633.

SrO is an even rarer constituent of basaltic rocks than is BaO. A similarly effective concentration in the case of copper would produce a high-grade cupriferous amygdaloid.

The prevailing trend of those who have recently had occasion to study the occurrence of zeolites in amygdaloids is to regard them as formed by the thermal waters of expiring volcanic activity. This conclusion is based in part on the occasional presence of datolite and apophyllite with the zeolites, pointing to boric and fluoric exhalations from the magma, and in part to the large difference in the character of the products of weathering with those of zeolitization.

In the Lake Superior amygdaloids, as is well known, there is believed[1] to exist "a close genetic relation between the metallic state of the copper and the ferric condition of the iron oxide in the associated silicates"—prehnite, epidote, delessite and others.

Weed and, later, Lewis have shown that not only is this explanation inadequate to account for the New Jersey copper deposits, but is also directly opposed to the facts found by them. Lewis,[2] basing a hypothesis on the fact that a hot cupric sulphate solution saturated with cuprous ions will deposit metallic copper on cooling, concludes that hot solutions of cuprous sulphate were released from the intrusive trap magma and that chalcocite was deposited near the hot trap masses, and as the solutions moved away to cooler regions, metallic copper was precipitated. This is a seductive hypothesis, but the assumption of a sulphate solution of direct magmatic origin appears in itself highly speculative.

The native copper occurrences of the Faroe Islands have recently been investigated by Cornu.[3] The metal is found associated with heulandite and desmine in the amygdules of Tertiary basalts, and also in the zeolitic binding material of some of the intercalated tuffs and breccias. The question of the genesis of these occurrences is considered a difficult problem. The deposits are regarded, however, as undoubtedly of pneumatolytic or hydro-

[1] *Am. Journ. Sci.*, 3d Ser., Vol. II., p. 353, 1871.
[2] Lewis, J. V., Geol. Survey New Jersey, 1906, p. 131.
[3] *Zeit. pr. Geol.*, 1907, p. 321.

thermal origin. The basis of this belief is not stated, but seems to be founded on the fact of the sporadic occurrence of a fluorine-bearing apophyllite along with the zeolites. On account of the absence of metallic sulphides in the region the mineralizing solutions are believed not to have contained sulphates, nor to have contained silicates, on account of the difficulty of reducing copper from such solutions.

In the case of the White River occurrences the presence of the carbon mineral is regarded as of particular genetic significance and affords a satisfactory explanation for the precipitation of the metallic copper from the mineral-bearing solutions. That any combustible substance will reduce metallic copper from its solutions at temperatures ranging between 150° and 250° was experimentally established by Senarmont in 1851. Geologically also there is considerable evidence available that carbonaceous matter is capable of precipitating metallic copper. On the other hand, it is found that chalcocite, instead of metal, is sometimes thrown down. Recently Lindgren[1] has described a commercial ore deposit from Springfield, Col., where chalcocite has been precipitated from a presumably cold sulphate solution by the reducing action of bituminous coal.

No explanation has been advanced yet as to why in some cases carbonaceous matter precipitates metallic copper and in others chalcocite.

While, then, the association of metallic copper and chalcocite with carbonaceous material is no novel feature, this particular association with zeolitic amygdaloids is, so far as the writer is aware, one not hitherto described. The occurrence of the combustible carbon mineral is doubtless genetically allied to the petroleum and asphaltum sometimes found with calcite in the vacuoles of basic lavas. An even more nearly analogous occurrence is the anthracite (96 per cent. C) found associated with the gangue material in the native silver-calcite veins of Konigsberg, Norway,[2] which are enclosed in country rock of igneous origin.

[1] Bull. U. S. Geol. Survey, No. 340, p. 172.
[2] Vogt, J. H. L., *Zeit. pr. Geol.*, 1899, p. 177.

An alternative hypothesis different from that implied in the preceding paragraph may be proposed to account for the origin of the carbon mineral associated with the White River occurrences. The ascending thermal solutions may have caught up woody material from some tuff beds underlying the cupriferous amygdaloids. Daubree[1] has shown that superheated water at a temperature near 500° will convert wood into an anthracite-like product, or at a less elevated temperature, into a lignitic product. Nothing, however, so far as now known of the geology of the region, favors this possibility.

[1] "Experimentale Geologie," p. 177.

THE MT. ROUDNY GOLD DEPOSIT.

JOSEPH T. SINGEWALD, JR.

Recent operations on a long since abandoned gold occurrence in Bohemia have brought to light some very interesting features. The deposit occurs on Mt. Roudny, about thirty miles south-southeast of Prague, and ten miles from Wotitz, the nearest railroad station, and was one of the earliest worked gold occurrences in Bohemia. It is said that the church in the neighboring town of Liboun was built by the early miners. The Roman style of architecture of this church would place the date of its erection before the twelfth century. Hence, if tradition is correct, mining dates back to that time; and the erection of a church by the miners would indicate fairly extensive and stable operations. Definite reference to mining here is first found in the latter part of the fourteenth century. During this early period no underground mining was attempted, but solely a washing of the weathered outcrops and the placers derived from the primary occurrence.

After having been long abandoned and forgotten, a second period of activity was inaugurated toward the close of the eighteenth century, when the property came into the possession of Count von Anersperg. During this period, underground mining was carried on, and two stamp mills erected for concentrating the ore. The gold was sent to the mine at Prague, in the archives of which the quantities delivered annually from 1769 to 1804 are given. After 1804 no further statistics are given; but operations struggled on until 1826, when the deposit was again abandoned.

In 1892 the deposit was prospected by Stantien and Becker, a Berlin company, and as a result of their investigation mining was again resumed. Owing to the use of primitive machinery and milling methods, however, the results did not come up to their expectations, and in 1903 the property was taken over by an

English syndicate represented by Dr. Albert Fischer and Herbert Stanley Sugden, of London. This company modernized the mine equipment, and built a new mill with a cyanide plant, and seems to be conducting quite stable and profitable operations. The annual output is about 12,000 oz. of crude gold, or 8,000 oz. fine gold.

According to Katzer's geological sketch map of Bohemia, Mt. Roudny lies within the region of the Archæan gneiss formation, which forms the greater part of southeastern Bohemia. The

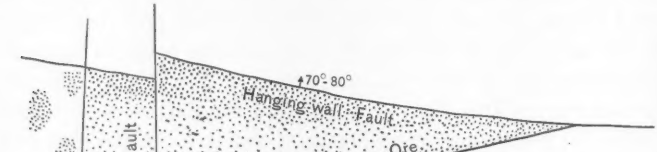


FIG. 22. Ideal Horizontal Section through the Mt. Roudny Ore Body.

outcrops on the surface, as well as those underground, show that the country rock in the neighborhood of the ore deposit is not a typical gneiss, but rather a granite, which in most places has taken on a gneissic structure as a result of subsequent squeezing. As proof that the rock in question is really a granite locally metamorphosed to a gneiss, and not a gneiss intruded by granite, is the fact that the gneiss grades over gradually into normal granite, which has absolutely no schistosity, and that it contains large and small amphibolite inclusions, which are resorbed on their surface, so that, in spite of complete discordance in the schistosity in the amphibolite and the gneissic granite, the two rocks grade into each other.

The normal granite consists of greyish quartz, bluish feldspar, and biotite. The gneissic granite has the same mineralogical composition, but is at times much folded and extremely schistose. In the amphibolite, fine-grained compact layers alternate with coarse-grained. These rocks are cut by aplite dikes, consisting chiefly of bluish plagioclase, flesh-colored orthoclase, and grayish quartz, and also frequently carry tourmaline.

Subsequent to the intrusion of the aplite, the region was affected by faulting at least three different times. The relations of these faults to each other are shown in Fig. 22. The oldest is a forking fault with a general east-west strike and a northerly dip. The southerly fork, or "foot-wall" fault as it is called, has a dip of about 50°, and the northerly, or "hanging-wall" fault, about 70° to 80°, so that the two forks approach each other in depth. In strike they converge toward the east. The line of junction of these two faults extends toward the west, with a dip of about 80°. Five hundred feet west of the junction of these faults is a north-south striking fault, dipping 80° W. near the surface, but becoming somewhat flatter in depth. From sixty to ninety feet west of it is a second fissure, parallel to it in dip, but converging slightly in strike toward the north. These two faults are usually spoken of together as the Paulina fault. This is a normal fault with a throw of unknown amount. In addition to the downthrow on the west, there has also been a side movement to the south, which has shifted the "hanging-wall" fault about thirty feet. The "foot-wall" fault dies out just before it reaches the Paulina fault. The distance between the two forks of the east-west fault, where they are cut by the Paulina fault, is about 200 feet.

A still younger fault is an east-west striking fault to the south, known as the Michaeli fault. It is approximately parallel to the oldest east-west fault, and has shifted the Paulina fault about 45 feet to the west.

The ore body lies between the "hanging-wall" and "foot-wall" faults, and is cut off on the west by the westerly fissure of the Paulina fault. It has, then, the general formation of a

triangular prism, broadening somewhat toward its base, and with its axis tilted about 10° to the east. In the upper levels there are two chief ore-bearing zones, one parallel to the "hanging-wall," and the other parallel to the "foot-wall" fault, which converge in depth. The country rock in these ore-bearing zones is cut by a large number of fissures, striking east-west and usually with a steep northerly dip. The individual fissures generally have a width of only a fraction of an inch, rarely reaching an inch in width, and are filled with quartz and pyrite. Connecting these fissures are a large number of transverse stringers also filled with pyrite and quartz, so that the entire rock is traversed by a network of such quartz-pyrite veinlets. Extending outward from these fissures, sometimes for a distance of several meters, the rock has been greatly altered. At times merely an impregnation with quartz and pyrite has taken place; at other times, the feldspar has been kaolinized, or it and the biotite replaced by quartz and pyrite. As a result of this alteration and impregnation, the zones in which the fissures lie have been converted into mineralized zones, which gradually grade off into the normal rock. These mineralized zones, together with the fissures that traverse them carry gold. The gold occurs chiefly in the pyrite, and it seems to be the rule that the more finely crystallized the pyrite, the higher the gold content. Free gold also occurs either in very finely divided condition in the quartz, or as small leaves and irregular crystals in crevices in the granite or between the planes of schistosity of the gneiss.

The shaft has now reached a depth of 715 feet, and in the lower levels where the work is being carried on, the two ore-bearing zones have graded into each other, so that the entire rock is mineralized, and with the exception of a few places that run too low in gold can be mined. Since the main ore is such an impregnated rock and veins are extremely subordinate, it is usually impossible to tell with the eye whether a given portion of the rock is rich enough to mine or not, and hence the mining is controlled wholly by assays. The amount of gold is extremely variable, and samples assay from practically nothing to $20 or more

a ton. In general, it decreases with increasing distance from the fissures, and is greatest in the fissures themselves.

The daily output is between 100 and 120 tons of ore, which averages nearly $6 per ton. On account of the character of the ore body and the cheapness of labor, this is said to yield a fair profit. Nearly 300 men are employed in the mine and about 75

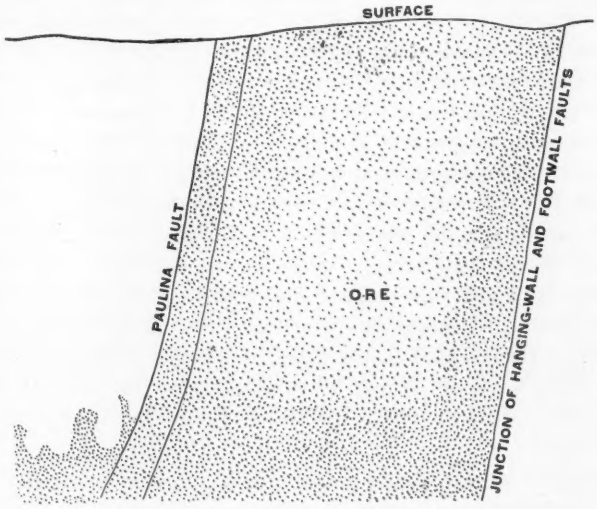


FIG. 23. Ideal Vertical Section of Mt. Roudny Ore Body parallel to Hanging-wall Fault.

on the surface. The wages are very low, averaging between 50 c. and 60 c. per day.

In addition to the main, or Wenzel shaft, there is another shaft, the Henrietta, which is used as a chute for dumping filling into the mine. As such a large percentage of the rock is workable ore, there is not enough waste for filling; hence, to prevent caving, the material from the settling dams is dumped back into the mine. This is brought up from the dams on an inclined

tramway and dumped into the old shaft, from which it is drawn off below as needed.

P. Krusch regards the mineralization as a result of mineral waters, which carried silicid acids, iron and gold, ascending in the crevices and fissures of the shattered country rock. These waters decomposed the granite, destroying the biotite and feldspar, and in place of these deposited finely crystallized gold-bearing pyrite and quartz. The width of the impregnated zone depended on the quantity of the circulating waters and on the greater or less resistance of the granite at a given point. The waters could continue to circulate until they had themselves closed the fissures as a result of mineral deposition. The intimate association of gold, pyrite and quartz does not permit the determination of an age sequence, but points to contemporaneous origin of these minerals. There are, however, indications of a gradual change in the character of the ore-bearing solutions. One frequently finds along the sides of the small veins the sulphide and quartz intimately intergrown, whereas in the middle the filling is solely quartz. Krusch infers from this a gradual dilution of the circulating waters. At first, when most highly concentrated, the finely divided pyrite which is richest in gold was deposited with the quartz. This was followed by the deposition of the more coarsely crystallized pyrite poorer in gold, together with quartz; and finally came the deposition of the pure quartz.

The ore deposition seems to have occurred subsequent to the older east-west striking fault, and before the movement along the Paulina fault. The limitation of the ore body on the north and south, by the "hanging wall" and "foot-wall" faults respectively, would indicate that the ore deposition occurred subsequent to the faulting along these fissures, and that the mineral-bearing solutions ascended along the fissures and cracks formed in the rock as a result of these movements. In the upper levels, the Paulina fault also cut off the ore body sharply on the west, and seemed to mark a boundary beyond which the ore-bearing solutions did not penetrate. With increasing depth, however,

drifts run beyond the fault have encountered masses of mineralized rock, which have become larger and more frequent on each new level. This in all probability is the upper boundary of just such an impregnated mass as is now being mined, and hence the continuation of the present ore body, which has been cut out in the upper levels by the Paulina fault (see Fig. 23). If this view is correct, a much larger ore body exists here than the early operations indicated.

The mill, which was completed in September, 1904, has attracted a great deal of attention on account of its complete and modern equipment. As the ore comes from the mine, it is immediately crushed to a 1⅝ inch size and dropped into bins of 200-ton capacity, which are connected with the mill by a tramway. The mill is built on the southeast slope of the hill, and arranged in three floors in conformity with the grade of the hill. The crushed ore is brought to the mill in tram cars and dumped into a large bin, from which by means of chutes it runs to six groups of stamps of five each, where it is reduced to a 900-mesh powder. The material is washed over amalgamation tables, which consist of silvered copper plates over which a layer of mercury has been brushed. The amalgamation continues until a layer 1 mm. thick has formed, when it is scraped off, and a new coat of mercury rubbed on the place. About 30 per cent. of the gold is obtained in this way.

From this stage on, the mill is arranged as a twin mill, the overflow from the first three amalgamation tables passing over one set of concentrating tables, and that from the other three over another set. This overflow goes to the next lower floor of the mill, where it runs over six tables arranged in two rows of three each. It is first washed over a 900-mesh sieve, through which the heavier particles fall; and these are concentrated on the first ten tables of the first row. The lighter materials, which flow over the sieve, go to the third table. The overflow from the latter is then further sorted, and passed over the three tables in the second row. The products from the tables are concentrates carrying 27 per cent. gold, tailings with 13 per cent., and slimes

with 6 per cent. The tailings, which also contain some slimes, then pass over three tables on the first floor, where concentrates are again obtained. The tailings from these last tables go to the cyanide plant, which is in a separate building below the mill. The slimes are mixed with lime to hasten precipitation, and allowed to settle in dams which have been constructed on the hillside just below the mill, adjoining the cyanide plant. As already mentioned, the material which settles here is used in the mine as filling. The clear water from the dams is pumped back to the central reservoir, and used again in the mill.

The water supply is derived from the mine waters, which are pumped out through the Wenzel shaft, and from a dam built across Ramena Creek, which flows along the south side of Mt. Roudny. In order to guard against a shortage, two wells have been put down which also flow into the dam.

THE ERZGEBIRGE TIN DEPOSITS.

PART II.

JOSEPH T. SINGEWALD, JR.

II. GEYER AND EHRENFRIEDERSDORF.

In the western Erzgebirge, the chief granite outcrop is the large Eibenstock granite massive, cutting across the mountains in a northwesterly direction with a width in places of over twelve miles. Tin deposits along the edge of this massive were formerly worked at a number of points but they were never of much importance. Farther east, however, about twelve miles from the main mass, are several outliers where tin is still being worked. These are the small outcrops at Geyer and Ehrenfriedersdorf.

The general geological features of this region are shown on the map in Fig. 2, taken from the Geyer and Ehrenfriedersdorf section of the geological map of Saxony. The prevailing rock is a muscovite schist, with bands of a gneissic mica schist. Within the area of outcrop of this schist are four small granite exposures—the Greifenstein, the Ziegelberg, a small outcrop between these, and the Geyersberg. The rock of all these exposures is characterized by the small amount of mica, the abundance of plagioclase, and the relatively large amount of topaz. In contrast to the Altenberg-Zinnwald granite, in which tourmaline was practically lacking, in this granite tourmaline occurs. Small grains of cassiterite are disseminated through the rock. While the above is the general mineralogical constitution of the rock, many different varieties are recognized, according as one or more of the constituents become more prominent, and through variations in texture.

In the neighborhood of the granite intrusions, the surrounding schist has been contact metamorphosed. This metamorphosed

rock is characterized by the presence of leaves of dark biotite and needles and tufts of andalusite. The nearer the granite contact is approached, the greater the degree of metamorphism; and this is expressed in increasing quantities of the secondary minerals, especially of the biotite.

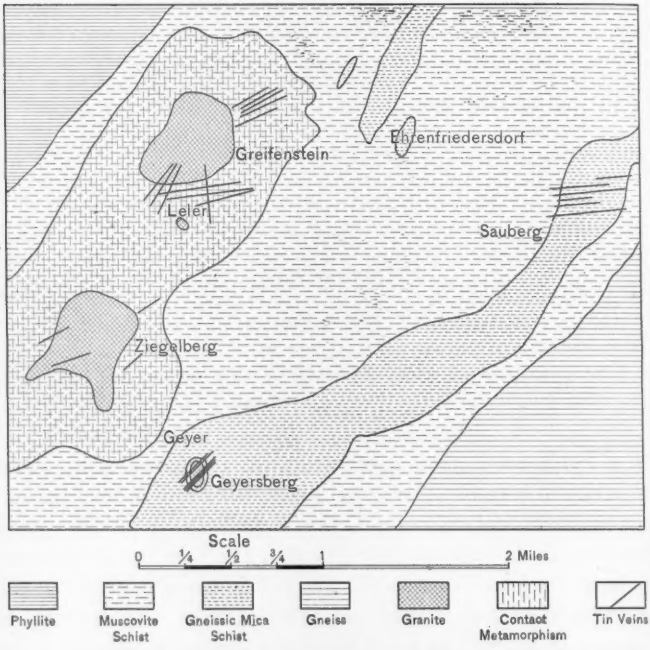


FIG. 24. Geological Sketch Map of the Geyer and Ehrenfriedersdorf Region.

The most important tin deposits are those at Geyer, on the south side of Greifenstein, and on the Sauberg to the east of the granite outcrops. After having been shut down for some time, these deposits have again been opened up within the last few years, and development work is now being carried on with a view of again making them productive.

1. *Geyer.*

The deposit on Geyersberg at Geyer was formerly the most important of these deposits, and mining was started here in 1315. As the result of the caving in of the old workings in 1803, a large "pinge" was formed, a view of which is shown in Fig. 25. The shattered rock in the "pinge" is now being quarried for road material.

The granite stock here dips with an angle of from 50° to 60° under the gneissic mica schists. The steep dip is no doubt one reason why the contact metamorphosed zone is so much narrower than by the other granite outcrops where the granite dips under its surrounding rocks at a much smaller angle. At the contact a typical friction breccia occurs. This is well exposed along the sides of the "pinge," and also at several places underground. Countless fragments of the surrounding rock in all sizes, some with sharp unaltered edges, and others with fused edges coalescing with the granite, are enclosed in a ground mass which is developed either as a very coarse-grained rock, or as a fine-grained rock with nests of coarsely crystallized feldspar.

The main mass of the granite, and also the adjacent rock, are traversed throughout by narrow bands of zwitter, in which the fissures from which the impregnation has taken place are usually so narrow as to be scarcely visible. In addition to these small irregular zwitter bands, there are groups of veins also accompanied by zwitter zones, and it is these veins that were formerly mined. They have a general northeast strike, and dip 70° to 80° to the northwest. The individual veins, which vary from ¼ to 4 inches in width, usually occur in groups of from three to twelve, about three to ten inches apart. On each side of the veins, the country rock has been altered to zwitter for a distance of about two to six inches, so that at times the zwitter bands coalesce, and the entire country rock in such a group of veins is converted into zwitter. The width of these vein groups varies from six to twenty-four feet, and between each group there is a wall of granite of about the same width. Nineteen such groups are known, but it is probable that there are still more, as at no

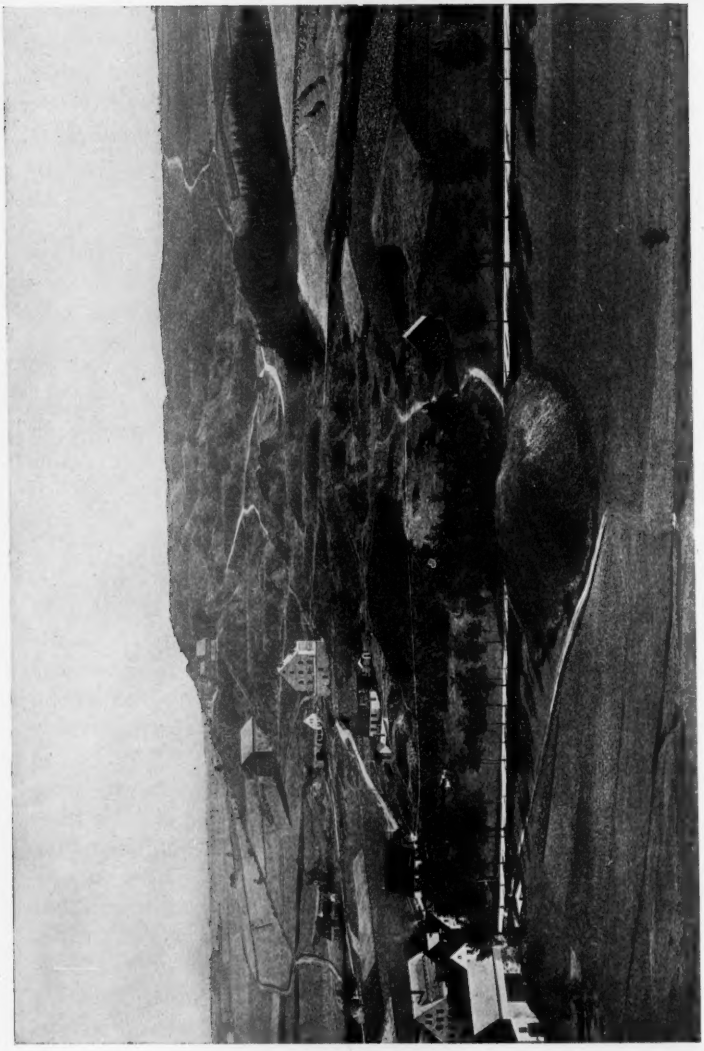


FIG. 25. View of the Sauberg, showing the many old dumps.

point has a level been run across the entire width of the granite stock. The principal ore in these veins is cassiterite, and wolframite occurs only in subordinate amounts. The gangue is chiefly quartz, topaz and mica. Fluorspar and tourmaline occur less frequently, and also an arsenic-rich arsenopyrite called gyrite.

Mining, which had been stopped here in about the 50's, was resumed three years ago; and although the underground force of twenty men is engaged principally in development work, there has been an annual output of a few tons of ore. The shaft has a depth of about 650 feet and goes down entirely in the schists. The lowest level is being extended northward into the granite in order to reach the groups of veins under the " pinge."

FIG. 25. View of the Sauberg, showing the many old dumps.

2. *Leier Mine.*

At the south end and also at the north end of the Greifenstein, tin veins cut through the granite and the adjoining contact metamorphosed schists. A force of about a dozen men are now engaged in development work on those at the south end for an English syndicate. The work is an extension of the old Leier mine, and is being carried out through two adit levels running north into the hill, at a difference in elevation of seventy feet. The levels go in on a dike of tin-bearing greisen, which cuts through the schists with a width of about three feet and a steep westerly dip. The dike is cut by two parallel faults, which approach each other in depth. The first or southernmost one shifts it about one foot to the west, and the second thirty feet. This dike has been followed as far as the granite contact, where it disappears. Crossing it, is a series of veins of somewhat later age, but they do not fault it. One of these veins attains a width of nine feet. These veins dip to the south, but with a steeper dip than the granite contact, so that they pass from the schists into the granite. When they reach the granite, however, they pinch out to mere fracture planes, and the ore is carried by the altered granite which occurs on both sides of the fracture. This altered granite is an ore-bearing greisen, which locally carries as much as 1 per cent. cassiterite.

These ores all carry a great deal of geyerite, so that the concentrates run nearly 30 per cent. in iron and arsenic.

3. *Sauberg.*

Southeast of Ehrenfriedersdorf on the Sauberg, tin veins occur in the gneissic mica schist, although no granite massive has been encountered. Mining began here in 1395, and the amount of work that has been done is shown by the large number of old dumps, which almost completely cover the surface of the hill (see Fig. 25).

In 1716, there were fifty shafts and adits. Mining had been discontinued for some time, when about three years ago the same syndicate that is working the Leier Mine put this mine in order again, and carried out some development work. The concentrates of this ore also run high in iron and arsenic, and further operations have been suspended while endeavoring to discover a method of extraction of the ore that will enable them to take advantage of the high arsenic content.

The veins here also occur in groups, which consist of from three to fifteen parallel veins, one to three feet apart. The average width of the veins is from two to ten inches, but locally they may attain considerable width. The general strike is between east and east-northeast, and the dip from 87° to 90° north or south. Five chief groups are recognized. The country rock is impregnated for a distance of several inches on each side of the vein with arsenopyrite. Cutting through the schists are minette dikes, and where the veins pass through them they frequently break up into stringers, which again unite on the far side of the dike. The tin veins are intersected by a younger system of cobalt silver veins, which have usually caused a slight displacement of the former. Although no granite stock has been encountered, the granite dikes which occur here would indicate the presence of such a stock at no great depth.

The present shaft has a depth of about 350 feet. On the lowest level a cross-cut extends out from the shaft, and from it

levels are run along the various workable veins. A zone with a width of nearly 700 feet has been exposed, in which there is a main vein with a number of secondary veins on each side. The secondary veins are not very persistent in length, but soon die out and are replaced by others. The main vein has an average width of about a foot and a half, and locally attains a width of three feet or more. Its character remains unaltered where it crosses the minette dikes, which is probably due to its greater width. The prevailing gangue is quartz, in which irregular masses of geyerite, cassiterite, and also abundant wolframite occur. The recent development work has disclosed an unusually rich secondary vein, from which magnificent specimens of cassiterite and wolframite crystallized in druses can be obtained. The faulting of the tin veins by a silver cobalt vein can be seen toward the west end of the levels, where such a vein has caused a shift of the tin veins of about one foot to the north on the west side. The silver cobalt vein at this point carried considerable native silver.

GENESIS OF THE DEPOSITS.

As is apparent from the above description of their occurrence, the genesis of these ore deposits is quite clear.

1. The granite contains as primary constituents fluorine and chlorine-bearing minerals as well as cassiterite.

2. All of the deposits occur in close association with granite intrusions.

3. The deposits are limited in the granite to its upper portion, and may extend beyond it into the surrounding rocks.

This is shown at Altenberg and Zinnwald, where their limit in depth has actually been reached, and also by the comparative lack of deposits in the two largest granite exposures—the Eibenstock granite in the west, and the Schellerhau in the east. The size of the outcrops shows that these granite masses have been more deeply eroded, and hence the top where tin deposits may have occurred has been removed.

4. The occurrence of the veins in the granite shows that their

formation took place subsequent to the intrusion of the granite, and after solidification had already set in.

5. The cutting of zwitter bands in the porphyry by granite dikes at Zinnwald shows that the ore formations had begun before the complete solidification of the granite.

These facts then all point to the granite magma as the original source of the ores. As the magma cooled, metalliferous gases and vapors escaped. When they reached the portion that had already solidified and the surrounding rock, they deposited their metallic contents, and also reacted chemically on those rocks. The vapors naturally most readily escaped upward, which accounts for the mineralization of that portion of the granite stocks. As the solidifying crust became thicker, the gases could no longer escape, and the formation of the ores ceased.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

MARKING OIL MAPS.

The symbols which have been most generally used in this country for the marking of oil maps are wide-spread and generally understood. This system, embracing only five symbols, does not, however, meet all the needs of oil map making so that two new systems have recently been introduced. The object of the present paper is to examine the merits and demerits of these proposals and to choose from the new symbols those that seem worthy of adoption.

In looking over the accompanying table the reader will observe that the new system proposed by the Gulf Pipe Line departs radically from the old system. Starting with the circle for location a dot is used to show the presence of a rig where the drilling has not yet started. When drilling has started a vertical line is passed through this dot within the circle. This is a great step in advance and deserves recognition. However, the Gulf Pipe Line system has met with much disfavor because of its inexplicable use of the time honored dry hole symbol for a gas well and of that for a showing of oil for an abandoned well. This leads to a great deal of confusion. Fortunately it has not been adopted by others as yet.

In the third column I have given the signs used by Messrs. Taff and Reed in U S. G. S. Bulletin No. 381 D, and as explained by the late Mr. Reed to me. It is difficult to see any

reason for introducing a new gas symbol so much unlike the old one when that is fairly satisfactory and so well known. I have found it a distasteful innovation to operators. The use of a vertical line for abandonment is also objectionable because it has been used for a show of oil.

The following considerations should guide one in the adoption of symbols.

1. The old and well-known symbols should be the starting point and should be used and built from so far as possible.

Old Signs.	Old.	Gulf Pipe Line.	Taff and Reed.	Proposed.
Location.				
Producing oil well.				
Producing gas well.				
Dry hole.			(1)	
Show of oil.		(5)	(1)	
Additional Signs.				
Rig.	(3)			
Drilling.	(3)			
Abandoned oil well.	(2)			
Abandoned gas well.	(4)	(1)		
Stopped above sand.	(5)	(1)	(1)	
Oil well spoiled.	(2)	(1)	(1)	
Special Signs.				
Missed sand.	(5)	(1)	(1)	
Water sand.	(5)	(1)	(1)	
Close sand.	(5)	(1)	(1)	
Good sand but no gas, oil or water.	(5)	(1)	(1)	
A specified shallower sand.				
A specified deeper sand.				
A specified additional sand.				

(1) = same sign as "abandoned." (4) = " " " "dry hole or gas well."
(2) = " " " "dry hole or oil well." (5) = " " " "dry hole."
(3) = " " " "location."

2. The symbols should be cumulative so that starting with a symbol for location this may gradually be added to, to express various stages of its history without any erasure.

3. The symbols should be as easily constructed as is consistent with the previous rules.

4. They should be such as to stand out boldly to the eye without careful examination.

In accordance with these rules the author has adopted for his

own use a system of symbols which is here presented for the consideration of other writers and map makers in the hopes that there may be as much uniformity in practice as possible. No argument, I believe, is necessary to justify the use of the five symbols and the two new ones for rig and drilling wells introduced by the Gulf Pipe Line. The presence of oil is always shown by a filled-in circle. The circle should not be filled in otherwise. It is not desirable to have any additional signs unless there are really good reasons, but experience in making maps for my own guidance in prospecting and for the use of buyers and sellers of oil properties has convinced me that it is desirable to introduce a few more symbols. The most pressing need is that for an abandoned well, which has been productive. An oil or gas well which has produced for several years and then been abandoned is very properly considered by the seller and prospector alike a very different thing from a dry hole. But at present map makers feel at liberty to represent these either as dry holes or wells. I have adopted the horizontal line for abandonment and this serves well in the case of oil wells. In the case of gas wells it necessitates the drawing of the horizontal line longer than the projecting lines.

I have met with two other conditions, which while ordinarily represented by the sign for a dry hole, are sometimes unjustifiably so treated. In one case are wells which have been abandoned above the principal producing horizon because the tools were lost, or legal complications intervened. Such wells have the appearance of being dry holes and their representation as such on maps has been the cause of serious loss. I suggest that a sign for such a hole be that of the dry hole with a slight modification as shown in the table.

Another contingency puzzling for the map maker is that of an undoubted oil well where abandonment was forced while the well was still potentially a producer. This happens from the loss of tools in the hole after it is practically completed, collapsed casing, or a shot placed too low which brings in an excess of water. Such a condition is seriously misrepresented by the sign

of a dry hole, and a new symbol is proposed in the table for such a well. This symbol should not be used except where the well was a potential producing well.

The author has found it desirable for his own use to use a slight modification of the dry hole sign to indicate the kind of dry hole that resulted. It is a great misfortune that oil operators are content to use the term dry hole for so many very different results. It is a convenient term to be used where the facts are not known except that oil in paying quantities was not found, but the prospector should never be satisfied without knowing, where possible, whether a dry hole was dry because the sand contained water, was absent, was insufficiently porous, or lacked oil for other reasons. If oil men were in the custom of using different symbols on their maps for these results and different names, such as a "water well," "missed well" or "close well" it would be a decided advance. It is very probable that the need of a fitter terminology would have brought such names into use was it not for certain peculiarities applying to the oil business which do not apply to mining, namely the large number of oil investors who know little of the actual conditions, the relative lack of a scientific literature pertaining to oil fields, and especially the fact that most of the drilling is done by contractors who are interested in turning over a completed well to the owner with as little information as is required.

The symbols of an ordinary oil map represent conditions in several sands. When a person is not thoroughly familiar with a particular locality, confusion and error is almost certain to result. It is of the utmost importance to know whether an oil well is producing from one or another of the several producing sands and if a dry hole which horizons it tested. It is therefore recommended that, except in general maps, the symbols should be differentiated for the different sands. Where different colors can be used, the matter is simple. But for blue prints this is not available and differing forms must be used. The circle should apply to the principal producing sand. The author suggests that a square be used for a specified shallower sand and a pentagon

for a specified deeper sand. In the uncommon case where still additional sands are involved in the same map, these may be represented by the hexagon, etc.

It is not a matter of very great importance that the particular additional signs here proposed should be adopted, but it is very desirable that there should be uniformity and that the present symbols should be increased in number and that this should be done in conformance with the four rules laid down above.

ROSWELL H. JOHNSON.

REVIEWS

Report on the Chrome Iron Ore Deposits in the Eastern Townships, Province of Quebec. By FRITZ CIRKEL. No. 29, Mines Branch, Dept. of Mines, Canada, 1909.

The chrome iron ore deposits of the eastern townships in Quebec are the most important which have been discovered in North America up to the present time; in fact, they are among the most important in the world. About one half of Mr. Cirkel's interesting and helpful report is devoted to descriptions of the deposits and the mining and milling operations in this district, while the other half contains sections on the occurrence of chromite in various parts of the world, on the uses and technology of chromium and its compounds, and on other subjects of general interest.

Chromium occurs in nature as chromite or chromic iron ore ($FeOCr_2O_3$) and as crocoite or lead chromate, the latter being very rare. Chromite has a theoretical percentage of chromic oxide of 68 and iron oxide of 32, but as it occurs in nature it rarely contains above 56 per cent. Cr_2O_3. This is due to the fact that alumina and ferric oxide replace part of the chromic oxide, and magnesia replaces part of the ferrous oxide. Silica and lime are also present as impurities. A small percentage of chromic oxide occurs in some varieties of other minerals, such as garnet, mica and titaniferous iron ore. Platinum has been found in association with chromite.

Chromic iron ore deposits are of two kinds: (1) primary deposits and (2) sands or secondary deposits. The former invariably occur in serpentine or associated basic rocks containing olivine, pyroxene and hornblende. It is either disseminated or concentrated into deposits. Chrome sands are formed from the disintegration of serpentines containing chromite and transportation of the latter and deposition along water courses.

Three classes of serpentine occur in Canada: (1) Laurentian serpentine, found in New Brunswick, in the Ottawa valley and in various parts of Ontario; (2) Huronian serpentine, found at a few localities in New Brunswick and Ontario, and (3) Cambrian serpentine, found in a belt extending from southern Vermont to Gaspe in the Province of Quebec. The Laurentian serpentines are yellow, light brown or green in color, and occur in association with crystalline limestone as disseminated

grains, local masses or interstratified beds. From the description given they appear to be ophicalcites. They have no chromite associated with them. The Huronian serpentines are not associated with crystalline limestone, but appear to have been derived from olivine rocks. A small amount of disseminated chromite occurs in them locally. The Cambrian serpentines are by far the most important in Canada, and in them occur the principal chromite deposits. Those in the southern part of the belt are associated with a series of schists, slates, and diorite, while those in the Gaspé peninsula are interstratified with slates and sandstones and some diorites. The former are clearly alteration products of olivine diabase or gabbro. They are locally tough and massive, but elsewhere they are fissured and slickensided. This is taken by Mr. Cirkel as evidence for great regional deformation and folding. It appears to the reviewer, however, from analogy with other areas, that much of this fissuring should be ascribed to deformation caused by pressure due to an increase in the volume of the rock during the alteration of the gabbro to serpentine. The alteration from olivine to serpentine, according to T. Sterry Hunt, is accompanied by an increase in volume of 33 per cent. The platy and schistose structure is so characteristic of serpentine areas, even where there has been a minimum amount of deformation, that it must be ascribed to some other cause besides regional deformation.

The principal chromite deposits are in the Thetford-Black Lake district; most of the producing mines being in the township of Coleraine. The deposits are largely in pockets and irregular masses in the serpentine; frequently having off-shoots into the wall rock. Many are near the contact of the serpentine with other rocks, but some large deposits occur within the serpentine areas. Considerable serpentine is found in the deposits, and considerable disseminated chromite is in the serpentine. Generally the deposits grade into the wall rock, though sometimes the contact is sharp. The deposits, as well as the wall rock, are much fissured and slickensided, and frequently faulting has occurred, bringing chromite in direct contact with barren serpentine, separated only by a slickensided fissure. The larger of these deposits may have dimensions varying up to 50 or 75 feet, rarely exceeding 100 feet. Their depth is problematic; the deepest mine at present is 340 feet. Several deposits frequently occur close together but not connected, and when one is exhausted a certain amount of dead work must be done before another can be mined. Most of the deposits are of limited extent.

The ore is of several types, according to the quantity of serpentine mixed with it. The highest grade deposits are composed of "crude" ore in which little serpentine occurs with the chromite. This ore, however, is not very abundant, the common types being those in which the chromite occurs in scattered kidneys or in disseminated

grains in the serpentine. The different types of ore are more or less associated in the same group of pocket. Many large deposits occur near the contact of rocks into which the serpentine is intruded, but others occur within the serpentine areas at some distance from the contact. Dikes of granite cut the serpentine in all directions and often chromite deposits are associated with them. It is believed by Mr. Cirkel that they have had a favorable influence on the deposition of this mineral. In some places chromite is found only on one side of the dike; elsewhere it occurs on both sides. Fragments of previously formed chromite locally occur within the granite dikes. Later in a chapter on the origin of the ores Mr. Cirkel indorses the theory that the chromite deposits are original segregations in igneous rock formed during the cooling of the mass. In this section he does not mention their occasional association with later granite dikes, and it is not very clear to the reviewer what part the latter are supposed to have played in the ore formation. It seems more reasonable to suppose that because of the abundant fissuring along some of the chromite zones they have become weakened and so the granite has broken through them rather than through the neighboring wall rock. This would account for the association and also for the presence of fragments of ore in the dikes. It seems possible, however, that locally granite dikes may have had the effect of segregating the disseminated chromite near-by, though this seems rather improbable, considering the insoluble nature of chomite.

In the section on the origin of the ores Mr. Cirkel gives the conclusions of other investigators of chromite and then endorses the theory of origin by magmatic segregation. Pratt in his study of the North Carolina chromite deposits comes to the conclusion that the ores originated during the cooling of the magma, the chromite separating out first according to the law of crystallization, and being concentrated where the cooling is quickest, *i. e.*, near the periphery of the cooling mass. The deposits would become smaller toward the interior of the mass. Power studied the New Caledonia deposits and found that chromite besides being disseminated in small grains through the serpentine, is concentrated along joints and water channels that could not have existed in the igneous mass at the time of solidification. Therefore he concludes that even though chromite is almost insoluble there must be some natural agent in force capable of decomposing it so that it may be redeposited. Hall and Humphrey in connection with their work on the chromite deposits in the Transvaal, find that the chromite grains when examined microscopically show perfect crystal outlines; their edges often encroaching on other crystals. This, together with the absence of a sharp line of demarcation between ore and country rock, they take as evidence that the ore is of igneous origin and must

be regarded as a concentration of scattered chromite grains. In conclusion Mr. Cirkel points out that the Canadian chromite deposits were formed during the cooling of the gabbro or peridotite magma by the crystallization of chromite before that of the other minerals and its local accumulation chiefly where cooling was fastest. This has produced the great irregularity in the form of the deposits which is further accentuated by later faulting.

The chromite industry of Canada dates from about 1898. The presence of chromite had been known for some time, and small quantities had been mined but there was no operation on a substantial scale. At present three companies are producing ore; all the mines being located near Black Lake and Thetford. The price of the ore varies from $9.50 to $15 per ton.

Several chapters are devoted to the mining and concentration of the ore, and another is devoted to detailed descriptions of the individual operations of the different mining companies and of a number of unworked prospects and outcrops. A brief general summary is given of the present knowledge of the chrome deposits of the world. Other chapters are devoted to analyses of chromite, statistics of production, determination of the value of chromite and the uses of chromium in alloys of iron, manganese, nickel, tungsten, and molybdenum, of chromite for furnace linings and of chrome salts as paints and in tanning leather.

E. C. HARDER.

WASHINGTON, D. C.

Annual Report on the Mineral Production of Virginia During the Calendar Year 1908. By T. L. WATSON. Bull. Virginia Geological Survey, No. 1–A. Charlottesville, 1909.

The report by the director of the Virginia survey on the mineral production of that state is a more generally interesting publication than its title implies. It is a well-arranged, accurately printed and judiciously illustrated brochure of 141 pages accompanied by a general map of Virginia showing the distribution of the various mineral deposits. The illustrations are, for the most part, carefully chosen maps and sections that convey definite information and are a refreshing contrast to the featureless, crudely executed half tones found in many state reports.

The introduction contains a tabulated statement of production for the year. This is followed by an excellent brief outline of the geology and physical geography of the state. The different mineral products are then taken up in order and are treated not only with reference to the local geologic features of their principal occurrences, but in such

a way as to exhibit clearly the relation of each kind of deposit to the broad natural divisions of the state, small outline maps being effectively used in this connection. The compactness, clearness and adequacy of the author's descriptions, accompanied as they are by references to important recent literature, show excellent judgment and testify, as does the whole work, to the professional skill in presentation that is to be won only by taking pains.

The report is a model of its kind and can be heartily recommended to anyone who desires to inform himself as to the mineral resources of Virginia. It should prove particularly valuable to teachers and students of economic geology in the state itself. It is of course a question how far, in successive annual reports of production, it is practicable or desirable to repeat the general information presented in the initial volume of the series. The reviewer is of the opinion that it is desirable at regular intervals, say of from three to five years, to publish in connection with the statistical material some such general physiographic and geologic outline as Mr. Watson has given, care being taken to bring it abreast of current information.

F. L. RANSOME.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN, J. A. ALLAN, AND S. J. SCHOFIELD.

METALLIFEROUS DEPOSITS.

GOLD AND SILVER.

Sur la formation des gisements d'or. By L. DE LAUNAY. Comptes rendus de l'Académie des Sciences. T. 149, pp. 298–300, 1909. Paris.

Three types of deposits derived from granitic magmas are distinguished according to their original depths—the California type exposed by little erosion, the Ural type, in more eroded country, and the Siberia type in still more eroded country. L.

Geologische en tecknische aanteekeningen over de goudindustrie van Suriname. (Geologic and technical notes on the gold industry of Surinam.) By E. MIDDELBERG. Amsterdam, J. H. de Busoy, 1908. Pp. 132, 1 map, 2 plates, 26 photos and 3 text-figures.

I., The geologic structure in the vicinity of the deposits. II., Occurrence and extent of the gold. III., IV. and V., deal with valuation methods of working, etc. (Geol. Zentralb., Bd. 13, No. 15, 708–711, 1910.) L.

Hoag District, California. By N. C. STINES. Min. and Sci. Press. Vol. 100, No. 11, pp. 384–386, 1910.

The ore occurs as veins in the basalt and andesite, and as replacement deposits along zones of shearing in the dacite. The filling is quartz. In the basalt and andesite chalcopyrite and carbonates of copper are present, while in the dacite, the ore metals are gold and silver which are free milling. A.

Mines of Ajuchitlan, Queretaro, Mexico. By S. J. LEWIS. Min. and Sci. Press. Vol. 100, No. 6, pp. 211–215, 1910.

The ore contains about 60 per cent. gold and the rest silver, and occurs as a "blanket" vein between shales which are capped by andesite. The ore bodies show evidence of downward leaching and

secondary enrichment, frequently concentrating the ore in pockets, Narrow bands of shale separate the shale beds, and all the rocks are extensively fractured and faulted. A.

Native Silver in Southwestern Chihuahua. By W. BRODIE. Eng. and Min. Jour. Vol. 89, No. 13, p. 664.

The native silver occurs in small quantities filling up splits or cracks in a vein, or finely disseminated or crystallized throughout the vein matter. Massive specimens are also found. The forms of the native silver are heavy spikes grouped in arborescent shapes and hair-like forms. It is associated with white calcite. S.

Paracale and Mambulao Districts, Philippine Islands. By W. D. SMITH. Min. and Sci. Press. Vol. 100, No. 13, pp. 453, 454, 1910.

Two ore bodies are described. One ore body lies in a brecciated zone lenticular in shape between andesite porphyry and shaly sandstone, which contains numerous calcite stringers. Some of these stringers carry free gold.

The other ore body is a "quartz filling" the contact between granite and diorite. Where the rivers cut across veins carrying gold a placer concentration is the result. Some of these are being worked. A.

Piz-Piz District, Nicaragua. By W. A. CONNELLY. Min. and Sci. Press. Vol. 100, No. 10.

The veins occur in flows of andesites which have been altered to a depth of 150 to 200 ft. The surface outcrop is richer and wider than the vein. The average value is $6 per ton. S.

IRON.

Die Eisenerze im Schweizer Jura. By E. RAUMBERGER. Mitt. d. nat. ges. Bern. 1907, pp. 58–67, Bern, 1908. (Geol. Zentralb., Bd. 13, No. 14, 1910, p. 664.)

Describes occurrence of (1) Jurassic oölitic ore, (2) brown ore of the lower chalk, (3) Tertiary *Bohnerze*. L.

LEAD.

Die Bleigänge von Mahuida in Argentinien. By S. MICHAELIS. Zeitschrift für praktische Geologie. Heft 10, XVII., p. 413.

The sedimentary basement series consist of limestone marl schists, sandstones, and conglomerates apparently of Jurassic age, broken through and overlain by neovolcanic andesites and basaltic rocks. The veins are associated with the oldest system of faulting, and occur in the sandstones, marl schists, and andesites. The ores consist of galena with barite as the gangue mineral. S.

St. Eugene Mine and Mill, East Kootenay, B. C. By E. JACOBS. Eng. and Min. Jour. Vol. 89, No. 8, p. 420.

The ores occur in quartzites in which a sheared and fissured zone is mineralized by sulphides, principally galena. Ore bodies are lenticular in shape and occur irregularly. An interesting feature is the interlacing veins, the drifts on which are designated "avenues." S.

MERCURY.

The Mercury Minerals from Terlingua, Texas. By W. F. HILLEBRAND and W. T. SCHALLER. U. S. G. S. Bull. 405, 1909, 174 pages.

A chemical and crystallographic study of the minerals kleinite, montroydite, terlinguaite, egglestonite, calomel, and mercury. L.

TIN.

Tin Mining and Ore Dressing in South Africa—III. By E. M. WESTON. Eng. and Min. Jour. Vol. 89, No. 11, p. 573.

The tin ores occur in sandstone and in granite, and in felsites and shales near their contact with sandstone. The granite which occurs in pipes contains the largest deposits which occur in irregular bodies and impregnations along joint planes. Tourmaline is associated with the tin ore. The origin ascribed to the metamorphism of the granite by pneumatolitic agencies. S.

NON-METALLIFEROUS DEPOSITS.

BARITE.

The Geology, Mining and Preparation of Barite in Washington County, Missouri. By A. A. STEEL. Bi. Mo. Bull. A. I. M. E. No. 38, 1910, pp. 85–117.

I., Geology.—Discusses paragenesis of minerals in some detail; summarizes geologic history; compares with other districts; discusses origin (derived from underlying pre-Cambrian rocks by deeply circulating meteoric water). II., Mining Industry.—Shows amount available and the output; the crude mining operations. III., Preparation for market. L.

CLAY.

Uber das Vorkommen der Porzellauerde bei Meiszen und Halle A. S. By J. E. BARNITZKE. Zeitschrift für praktische Geologie. Heft II., XVII., p. 451.

He discusses the distribution and the deposits of china clay giving a map and three cross-sections as illustrations. In dealing with the

origin numerous laboratory experiments on the artificial production are described. The author is inclined to the theory that the deposits originated by the atmospheric weathering different from today on feldspathic rock. S

COAL.

Coal Resources of Washington. By R. P. TARR. Mines and Minerals. Vol. 30, No. 5, 1909, pp. 311–314.

The coal seams are exposed in the canyon walls of the Carbon River. The field is eight miles long. Massive andesites have been intruded into the series, and through foldings the carbon accumulations have been converted into a good steam coal. The thickness of the seams varies and reaches a maximum of about eleven feet. A.

Controller Bay Coal Fields, Alaska. By G. W. EVANS. Mines and Minerals. Vol. 30, No. 8, p. 449; No. 9, p. 552.

The coal field is grouped into the Stillwater, Kushtaka and Tokum stages of the Tertiary Period. The Kushtaka is the coal-bearing member of the above group and appears in irregularly shaped patches in the field. The whole field might be considered as a monocline with a 45-degree dip to the northeast and with a northeast and southwest strike. Folding and faulting occur. Igneous intrusions cut the shale in many places. S.

The Nicola Valley Coal-Field, British Columbia. By M. ROBERTS. Bi.-Mo. Bull. A. I. M. E. No. 37, 1910, pp. 27–32.

A brief general description. L.

La houille du Sud-Oranais. By Gén. JOURDY. Bull. Soc. Sci. Nat. Ouest, France. 2 sér., t. VIII., 1908, pp. 97–113, pl. III. and IV.

Relates the discovery of the coal and circumstances methodically leading to it. L.

NITRATES.

The Nitrate Deposits of Chile. By R. A. F. PENROSE, JR. Jour. Geol., XVIII., 1, 1910, pp. 1–32.

Contents: location; history of industry; natural features of the nitrate regions; mode of occurrence in the Tarapacá region; materials composing the deposits in the Tarapacá region; other regions in Chile; origin of the nitrate deposits in Chile; industrial features in the Tarapacá region; deposits elsewhere than in Chile. L.

Nitrate of Soda Industry in Chile, I. By S. H. LORAM. Min. and Sci. Press. Vol. 100, No. 3, pp. 125–129, 1910.

The range in which the deposits occur is made up of diorite and

aphanitic volcanics on the east and eurite on the west, with some patches of limestone between of probable Jurassic age. The deposits occur in the stratified deposits between the two igneous masses and at altitudes from 500 to 2,000 meters above sea-level. The nitrate-bearing mixture is known as "caliche." Workable deposits must be over 30 m. thick and carry over 18 per cent. nitrate of soda. Various theories are cited. The writer holds the electrical theory as the most probable one. The electrical conditions in this desert area are of unusual abudance. Oxides of nitrogen would be produced by the friction of the winds on the ground, from which nitric acid would be formed in the presence of the dense fogs which cover this area nightly. This product with the carbonate of soda derived from the disintegration of sediments would form nitrate of soda.

Pt. II., Vol. 100, No. 5, pp. 180–184. Describes briefly the various companies in operation and the methods of extraction. A.

OIL AND GAS.

Die Geologie, Gewinnung und der Transport des Erdöls. By H. HÖFER, Leipsig, S. Herzel, 1909, p. 967.

The second volume of a monograph on hydrocarbons. 738 pages devoted to general and local geology of oils, gas, etc. L.

Geology of Oil and Gas. By E. HAWORTH. Mines and Minerals, Vol. 30, No. 9, p. 538, 1910.

In many fields there is a definite relation between the local geologic structure and the pools of oil and gas. However, this is not always the case. The anticline alone does not produce the oil and gas, but it must coincide with the two conditions: firstly there must be a proper accumulation of sand or other porous rock, and secondly, the oil and gas must be forced into such rock from "nature's laboratory." Some exceptional cases are cited. A.

PRECIOUS STONES.

Benitoite, its Paragenesis and Mode of Occurrence. By G. B. LOUDERBACK, with chemical analyses by W. C. BLASDALE. Univ. of Cal. Publications, Vol. 5, No. 23, pp. 331–380, pls. 27–39, 1909.

Summarizes geology; gives general relations of the minerals, describes the crystallography, physical and chemical characters, and gem quality of benitoite; describes the associated minerals (chiefly neptunite, natrolite and copper minerals) alteration of country rocks (mostly serpentine), sequence of events, distribution of minerals in veins, relation to the serpentine; concludes with a general discussion. L.

SALT.

Sur le chlorure de sodium de l'Oasis de Bilma. By A. LACROIX. Bull. Soc. française de Mineralogie. T. 31, pp. 40–43, Paris, 1908.

Contains brief accounts of the salt deposits and industry of the district. L.

STONE.

The Granites of Vermont. By T. N. DALE. U. S. G. S. Bull. 404, 1909, pp. 138.

Part I., Scientific discussion: includes condensed and general petrographic and geologic descriptions, and outlines the earlier geologic history of Vermont granites. Notes a hitherto unrecorded case of double sheet jointing. Part II., Economic Discussion: describes in detail the granites and quarries of the several districts; also notes general characters and adaptation, classification, commercial values, statistics of production, and methods in the use of explosives; concludes with bibliography and glossary. L.

Marmorlagerstätten Karnteus. By P. EGENTER. Zeitschrift für praktische Geologie. Heft 10, XVII.

He describes the petrographic character of marble. Several localities are dealt with in detail. As to the origin of the deposits described, he says—The marble was originally a sedimentary formation which was altered by the contact metamorphism of granite. S.

Shaw's Park Marble Deposits. By A. LAKES. Min. Sci. Vol. 61, No. 1567, p. 124.

The deposits occur in Twin Mountain which consists, at the base, of red granite overlain by Cambrian quartzite, Silurian limestone and marble and lower Carboniferous limestone. The zone which has been altered into marble is the dolomite of the Silurian and the limestone of the Carboniferous. S.

TALC.

Talc Mines and Industry of North Carolina. By C. HOFER. Min. World. Vol. 32, No. 7, p. 377.

The deposits are located near the junction of the sedimentary rocks and the crystalline schists and the pyrophyllite is the product of the metamorphosed sedimentaries or altered igneous rocks. The origin of the pyrophyllite is similar to that of the talc, having altered from feldspar or mica. S.

WATER.

The Quality of Surface Waters in the United States. Part I, Analyses of waters east of the One Hundredth Meridian. By R. B. DOLE. U S. G. S. Water-Supply Paper 236, 1909, pp. 123.

Gives methods of analysis, location of sampling stations, and analytical results. L.

REGIONAL REPORTS.

Geological Notes on West Coast of Mexico. By C. W. BOTSFORD. Eng. and Min. Jour. Vol. 89, No. 4, p. 223.

The geology and topography of the western coast of Mexico is summarized. Copper deposits occur as contact deposits, a combination of contact and vein deposits and disseminated in schists. Silver veins, the most common, occur in the andesites and in the sedimentaries. Iron ores occur along limestone contacts in large bodies. The primary mineralization took place at close of the first eruption period (Eocene) and during the following long period of erosion secondary concentration took place before the later rhyolite eruptions. S.

Geological Distribution of the Precious Metals in Colorada, I. By T. A. RICKARD. Min. and Sci. Press. Vol. 100, No. 2, Jan. 8, 1910, pp. 89–96.

The writer has compiled a table which illustrates the geologic distribution of the precious metals in the State. Eighty-five mining localities are cited which are represented by about 650 mines. The country rock of each locality is tabulated and the geologic period to which it belongs. A brief description of its most imporant localities is given. The writer states that his article is "merely a systematic effort to bring out a dominant fact in the study of ore deposits in Colorado."

Pt. II., Vol. 100, No. 4, pp. 150–155. Continues the more detailed description of certain deposits especially those of Rico which occur in limestone and shale.

Pt. III., Vol. 100, No. 9, pp. 316–320. Describes the localities in the Cripple Creek district. A.

Notes on Some Mining Districts in Humboldt County, Nevada. By F. L. RANSOME. U. S. G. S. Bull. 414, 1909, pp. 75.

Summarizes history of mining development, gives bibliography, and describes the following districts: Seven Troughs, Rosebud, Red Butte, Humboldt Range, Pahute Range, and Sonoma Range. Describes mineralogy of the ore deposits, and classifies the several types of ore deposits in the region as antimonial silver, gold-silver, copper, antimony-quicksilver, and nickel-cobalt deposits. Ore deposition took place following granodiorite intrusions, during late Mesozoic and early Tertiary time. L.

Preliminary Report of the Mineral Production of Canada during the calendar year 1909. By J. MCLEISH. Can. Min. Jl. Vol. 31, No. 6, 1910, pp. 170–175.

Shows in tabulated form that the total mineral production for the year was about $90,000,000 or an increase of over 5 per cent. on the production of 1908 which was $85,927,802.

The order of production is—coal 27 per cent., silver 15.9 per cent., gold 10.8 per cent.; nickel 10.5 per cent.; copper 7.8 per cent.; cement 5.8 per cent.; clay 6.1 per cent. and asbestos 2.5 per cent. A.

Russia's Gold and Copper Production. Specially compiled for The Mining Journal. Vol. 88, No. 3883, p. 90, 1910.

Gold is produced in three districts: the Urals, western Siberia and eastern Siberia. The first two show a rapid decrease in the gold production while the third shows an increase. The total production was about 2,560 poods (1 pood = £1,922). There has been an increase of about 1,200 tons in the production of copper for 1909. A.

ORE DEPOSITS.

The Genesis of the Leadville Ore-Deposits. By M. BOEHMER. Bi-Mo. Bull. A. I. M. E. No. 38, 1910, pp. 119–122.

Cites evidence from the more recent workings on Breece Hill to prove that ores originally ascended after dike intrusions through deep fissures, and were later concentrated by downward circulating surface water, thus duplicating the provisional conclusions of Emmons and Irving (U. S. G. S. Bull. 320). Suggests that the Missouri Pb and Zn ores had a similar ultimate origin. L.

L'Intervention et le Role de l'Eau dans les Phénomènes volcaniques. By M. A. GAUTIER. Annales des Mines. Tome XVI, 9th Liv. de 1909.

The author holds that the water in a volcanic eruption is a constant product of the internal reactions of the globe and of its eruptions. In these waters of igneous origin are found fluorine, boron, phosphorus, iodine, arsenic, iron, carbonates, sulphur, silicates, chlorides, ammonia, free oxygen, argon and its associates which point to its juvenile origin. S.

Problems of Ore Deposition in the Lead and Zinc Veins of Great Britain. By A. M. FINLAYSON. Min. Jour. Vol. 88, No. 3886, p. 169.

The ores were transported in the deeper zones by juvenile waters in which fluorine was an important constituent, while in upper regions meteoric waters came into play. The vein solutions carried (1) alkaline sulphides which held sulphides of the metals in solution (2) alkaline and earthy carbonates. The filling of the fissures was by replacement of the rocks by ores. The country rock had an influence on the ore deposition. S.

Recent Developments on Iron Hill Leadville. By G. O. ARGALL. Eng. and Min. Jour. Vol. 89, No. 5, p. 261.

The geology of the Iron Hill is reviewed. The conclusions concerning the genesis of the deposits are as follows: (1) The mineral deposits of Leadville are so diversified that no one theory will cover them. The deposits of copper, bismuth and other minerals cannot be secondary. (2) The pay-shoots in the limestone bear a genetic relationship to the gray porphyry. (3) Ascending solutions permeating the Cambrian quartzites played an important part in the formation of the ore bodies of Iron Hill. S.

SCIENTIFIC NOTES AND NEWS[1]

A SECOND STATEMENT has been received from the secretary of the International Congress of Mining, Metallurgy, Applied Mechanics and Practical Geology which is to be held at Düsseldorf between the nineteenth and twenty-third of June of the present year. Those who participate in this Congress may do so under the head of (*a*) Honorary Members; (*b*) Patrons of the Congress (those who contribute not less than 100 marks [$23.80] to the funds); (*c*) Ordinary Members (those who pay a subscription of 20 marks [$4.76] for membership in any of the four sections). Members attending the congress may participate in the proceedings of any other section than that in which they are registered by the payment of 5 marks [$1.19] additional. Honorary members of the congress and patrons will receive all printed reports of the congress, but ordinary members will be entitled to receive the reports of that section only in which they have registered. They can, however, enroll themselves in any other section and receive the proceedings of that section on payment of the additional charge of 5 marks.

The provisional programme of the congress is as follows:

Saturday, June 18, 1910. Opening of the Congress Office in the "Tonhalle" (hours from 10 till 5).

Sunday, June 19, 1910. Congress Office in the "Tonhalle" open from 10.30 to 3; 8 P. M. to 11 P. M.; informal meeting of the members of the congress.

Monday, June 20, 1910. 9.30 A. M., opening ceremony of the congress. 11 A. M. to 1 P. M., assembling of the sections —formation of these, followed by first meeting of the sections.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

1 to 2.30 P. M., luncheon of the members together. 2.30 to 5.30 P. M., second section meeting. 8 P. M., evening reception given by the town of Düsseldorf.

Tuesday, June 21, 1910. 9 A. M. to 12.30 P. M., third meeting of the sections. 12.30 to 2 P. M., luncheon of the members together. 3 to 5 P. M., fourth meeting of the sections or afternoon excursions. 7.30 P. M., grand banquet.

Wednesday, June 22, 1910. 9 A. M., fifth meeting of the sections, if found necessary; otherwise excursions. Evening, trip up the Rhine to beyond Duisburg.

Thursday, June 23, 1910. Excursions. 5 P. M., concluding meeting of the congress in the "Städtische Saalbau" to Essen, followed by a garden-party.

In the Section for Practical Geology the following papers will be read. Many of them promise to be of unusual interest to students of economic geology.

Professor Dr. Ch. Barrois, Lille, "The Origin of the Clastiques Coal Deposits and the Erratic Blocks Found in the North of France."

Geh. Bergrat Professor Dr. Beyschlag, Berlin, "Communication on the Iron Supplies of the World."

Dr. Fliegel, Berlin, "The Tectonics of the Lower Rhine Inlet and their Importance for the Development of the Lignite Formations."

Mining Engineer Krahmann, Berlin, "The New Mineral Deposit Policy and its Problems."

Professor Dr. Krusch, Berlin, (*a*) "The Otavi Copper Ore Deposits from the Genetic and Politico-Economic Points of View"; (*b*) "The Radium Deposits and the Probable Development of the Radium Market."

Bergassessor Kukuk, Bochum, "The Tectonic Conditions of the Lower Rhine-Westphalian Coal Deposits in View of the Latest Explorations."

Reg. Baumeister a. D. Link, Essen, "The Dams of the Ruhr District with Special Consideration of the Möhne Valley Dam."

Bergassessor Macco, Cologne, "Mining Economics, their Substance and their Limits" (in common with Section I).

Mine Surveyor Mintrop, Bochum, "On Artificial Earthquakes."

H. Mortimer-Lamb, Montreal, "The Unique Mineral Resources of Canada."

Professor Dr. Potonié, Berlin, "The Origin of Coal."

Geological Engineer Renier, Liège, "The States of our Knowledge of the General Stratigraphy of the Belgian Coal District."

Director General Schulz-Briesen, Düsseldorf, "Importance of Practical Geology in Science and Political Economy."

Geh. Bergrat Professor Dr. Steinmann, Bonn, "On the Combined Ore Veins in the Cordilleras of South America."

Privat-Dozent Dr. Wegner, Münster, "Underground Water Conditions of the Münster Country."

Additional papers on subjects to be communicated later have been promised by Messrs. Dr. Bärtlin, Berlin; Professor Holtz, Aix-la-Chapelle; Professor Dr. Michael, Berlin; Professor Dr. Scheibe, Berlin; Professor Dr. Stille, Hanover; Mine Surveyor Wachholder, Düsseldorf, and Dr. Wunstorf, Berlin.

All communications and applications for membership should be addressed to the "Arbeitsausschuss des Internationalen Kongresses Düsseldorf, 1910."

THE NINETY-EIGHTH meeting of the American Institute of Mining Engineers was held at Pittsburg, Pa., from March 1 to 4, 1910. The opening session on Tuesday evening, March 1, was held in the large lecture hall of the Carnegie Institute, President David W. Brunton presiding. Harrison W. Craver, secretary of the local committee, introduced Dr. John A. Brashear, who delivered the welcoming address, to which President Brunton responded. The following addresses were given:

Dr. R. W. Raymond: An oral abstract of biographical notice of the late Dr. Charles B. Dudley.

Col. H. P. Bope: A eulogy of the late William Metcalf.

Prof. Robert H. Richards, past president of the institute: "Development of Hindered Settling Apparatus," illustrated by lantern slides.

L. T. Beyl: A brief description of the mining districts of the Argentine Republic, illustrated by lantern slides.

The program on Wednesday morning was as follows:

"Systematic Exploitation in the Pittsburg Coal Seam," by F. Z. Schillenburg and Edward McGrew, Pittsburg, Pa. Discussed by Frank W. DeWolf, geologist of the Illinois State Geological Survey.

"A Commercial Fuel Briquetting Plant," by William H. Blauvelt, Syracuse, N. Y. Discussed by C. W. Malcolmson, Chicago, Ill.; E. W. Parker, U. S. Geological Survey, and J. Birkinbine, Philadelphia, Pa.

"Dust Explosions in Coal Mines," by George Samuel Rice, Pittsburg, Pa.

"The Gaseous Decomposition Products of Black Powder," by C. M. Young, Lawrence, Kan.

"Work of the Technologic Branch of the U. S. Geological Survey at Pittsburg, Pa.," by Dr. Joseph A. Holmes, Washington, D. C.

Wednesday afternoon was devoted to a visit to the testing station of the U. S. Geological Survey at Arsenal Park.

On Wednesday evening the following papers were presented:

"Accumulation of Petroleum in the Earth," by David T. Day, Washington, D. C.

"The School of Mines at the Pittsburg University," by M. E. Wadsworth, Pittsburg, Pa.

"The Technical Schools of the Carnegie Institution," by Fred Crabtree, Pittsburg, Pa.

"A New Method of Cyaniding Gold and Silver Ores," by E. Gybbon Spilsbury, New York.

"The Dwight and Lloyd Sintering Process," by Arthur S. Dwight, New York.

On Thursday morning, through the courtesy of the Carnegie Steel Company, a party of about one hundred visited the steel works at Homestead, afterward lunching at Newhall, and devoting the afternoon to special trips to the electric steel furnace of the Carnegie Steel Company and the plant of the Mesta Machine Company.

On Friday the following papers were presented:

"The Huronian as a Gold-bearing Terrane," by Robert Bell, Ottawa, Can.

"The Action of Explosives in Rocks of Different Degrees of Hardness," by W. O. Snelling, Pittsburg, Pa.

"History of the introduction of Basic Steel in the United States," by George W. Maynard, New York.

"Electric Mine Hoists," by Karl A. Panly, Schenectady, N. Y.

"Field Investigations of Structural Materials for Use in Federal Buildings," by E. F. Burchard, Washington, D. C.

"Coal and Iron Ore in Western Oaxaca, Mexico," by J. L. W. Birkinbine, Mexico, D. F.

"The Chemical Control of Slimes," by Harrison E. Ashley, Pittsburg, Pa.

THE TWELFTH annual meeting of the Canadian Mining Institute was held at Toronto, March 2, 3 and 4, 1910. The attendance was large, 152 members being registered. After a brief address of welcome, President Miller delivered his annual address. The report of the council showed a total membership of 935, including active, associate and student members.

A paper was then read by J. McLeish, giving a summary of his report on the mineral production of Canada in 1909. This was followed by a report by Thomas W. Gibson on the same subject. He reported the silver output for the year as the largest in the history of the province. Theodore C. Denis, Superintendent of Mines of Quebec, also reported on that province.

A business meeting was then held. The report on the competition for the prizes offered for papers by student members stated that the council had awarded the president's gold medal to N. L. Bowen, of the School of Mining, Kingston. In addition Mr. Bowen received a cash prize of $25; while cash prizes of $25 and $20 respectively were awarded to E. P. Cowles and G. J. Burland, both of McGill University. Papers submitted by Messrs. Rider, Rutherford and White received honorable mention.

In the afternoon the following papers were read and discussed.

"The Necessity of Distinguishing Between Prospecting, Developing and Mining," by R. W. Brock, Ottawa.

"Mining Engineers and Mining Institutes," by P. D. Kendall, London, England.

"The Helen Mine, Michipicoten, Ontario," by R. E. Seelye, Sault Ste. Marie, Ont.

"Iron Ores in Vancouver Island," by E. Linderman, of the Mines Department, Ottawa.

The evening session was devoted to electro-metallurgy, two papers being read: "Recent Developments in Electro-Siderurgy," by P. McN. Bennie, Niagara Falls, and "Steel from the Electric Furnace," by Dr. A. Stansfield, Montreal. Both papers were illustrated by lantern slides and were exceedingly interesting.

The morning session on Thursday, March 3, was devoted largely to asbestos. Three papers were read on "The Origin of Asbestos," by Dr. A. E. Barlow, of Montreal; on "The Distribution of Chromite and Asbestos Deposits in the Eastern Townships of Quebec," by John A. Dresser, and on "Recent Developments in the Thetford Asbestos Region," by W. J. Woolsey, Thetford Mines, Quebec. These papers called out extended debate. A short paper on "Mining Literature," by Allen Greenwall, of London, England, was read and called out a discussion in which Doctor Wilmot, Professor Walker and Mr. Hobart took part.

On Thursday afternoon the question of amendments to the by-laws was taken up, and caused much discussion. Several amendments which were merely verbal improvements in the old by-laws, were passed. The most important, providing for an entirely new classification of members, with restriction of full membership to those possessing certain technical qualifications, was rejected after sharp debate, and amendments providing for certain geographical restrictions in the membership of council and for the appointment yearly of a nominating committee to which all nominations for membership should be referred and which should present candidates for officers were also voted down after

debate. Following this business, addresses were given by Dr. James Douglas, of New York, on copper mining in Megantic County, and J. W. Wilson, of Ottawa, describing a number of old mines recently examined in the Megantic region.

On Thursday evening, Dr. J. D. Irving, of New Haven, Conn., read a paper on the formation of ore deposits by replacement, illustrated by lantern slides. After the reading of this paper a smoker was held, presided over by G. G. S. Lindsey, during which a handsome testimonial was presented to Major Leckie, the senior member of the institute both in age and period of membership.

At the morning session on Friday the following papers were presented:

"Some Reminiscenses of Two Well Known Mines," by B. B. Lawrence of New York.

"Criteria of Downward Sulfide Enrichment," by F. L. Ransome of Washington, D. C.

"Some Directions in which Improvements in Concentration May be Looked For," by R. H. Richards of Boston, Mass.

On Friday afternoon Dr. Heinrich Ries, of Ithaca, N. Y., read a long paper illustrated by lantern slides, on the "Clays of Nova Scotia." There was a lengthy debate on this paper.

The following officers were elected for the ensuing year: President, Frank D. Adams, Montreal; vice-presidents, A. B. W. Hodges, of Grand Forks, B. C., and R. W. Leonard, of St. Catherines, Ontario. Councilors, Arthur A. Cole, of Cobalt, Ont., Charles Fergie, of Montreal; J. B. Tyrrell, of Toronto; John A. Dresses, of Ottawa; G. G. S. Lindsey, of Toronto; O. E. S. Whiteside, of Coleman, Alberta; Selwyn G. Blaylock, of Moyle, B. C.; Robert A. Bryce, of Cobalt, Ont.; R. A. Hopper, of Montreal, and John J. Penhale, of Sherbrooke, Quebec.

The meeting was closed by the annual dinner on Friday evening, which was marked by some excellent speaking.

The formal proceedings were closed by a brief valedictory speech by W. G. Miller, the retiring president, responded to by Dr. F. D. Adams, the new president.

THE ELEVENTH ANNUAL MEETING of the Cordilleran Section of the Geological Society of America was held on Friday and Saturday, March 25 and 26, 1910. The following papers were presented:

"The Paragenesis of Minerals," by Austin F. Rogers, Palo Alto, Cal.

"The Occurrence of the Halogen Salts of Silver at Tonopah, Nevada," by J. A. Burgess, Tonopah, Nev., and A. S. Eakle, Berkeley, Cal.

"Ruby Corundum from San Bernardino County, California," by George D. Louderback, Berkeley, Cal., and W. C. Blasdale, Berkeley, Cal.

"California Earthquakes—A Synthetic Study of the Recorded Shocks," by H. O. Wood, Berkeley, Cal.

ON MONDAY, APRIL 4, at the meeting of the New York Academy of Sciences, Dr. John M. Clarke, of New York, presented a paper on "The Geological Survey of the State of New York."

PROFESSOR C. K. LEITH AND MR. W. J. MEAD, of the University of Wisconsin, have a party of graduate students in geology with them and are spending the month of May in the detailed mapping of the pre-Cambrian rocks of the Menominee iron-bearing district of Michigan. This work is part of the regular course in geology at the University of Wisconsin.

THE FOLLOWING PAPER of unusual interest was read at the twenty-first meeting of the Geological Society of Washington at George Washington University on Wednesday, April 13, 1910, by Mr. W. H. Emmons: "Recent Experiments Relating to the Transfer of Gold by Cold Dilute Mine Waters.

THE ELEVENTH SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS will be held in Stockholm, Sweden. The meeting will begin on August 18, 1910, and will close on August 28.

The session of the congress will be devoted to the presentation and discussion of the following five topics: (1) "The Geology of the Precambrian Systems," (2) "Climatic Changes Since

the Maximum of the Last Glaciation," (3) "The Iron Ore Resources of the World," (4) "The Geology of the Polar Regions," (5) "The Sudden Appearance of the Cambrian Fauna." The most important feature of the congress will be the detailed and careful consideration of the iron ore resources of the world. A volume has been in preparation for a considerable time setting forth the resources of the world in this metal. Eminent specialists in every country have been employed in its compilation and it will be published by the congress. Subscriptions for the volume should be sent in at as early a date as possible.

Excursions will be held both before, during and after the sessions to points of interest to students of geology.

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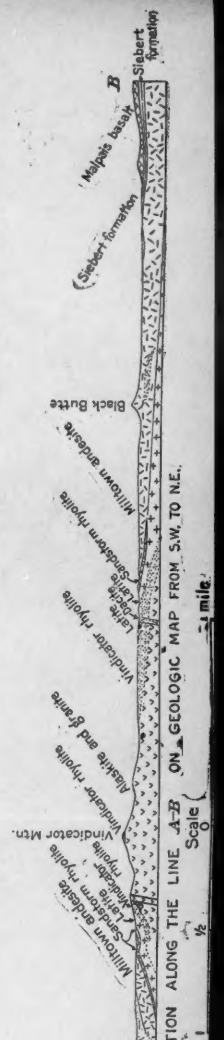
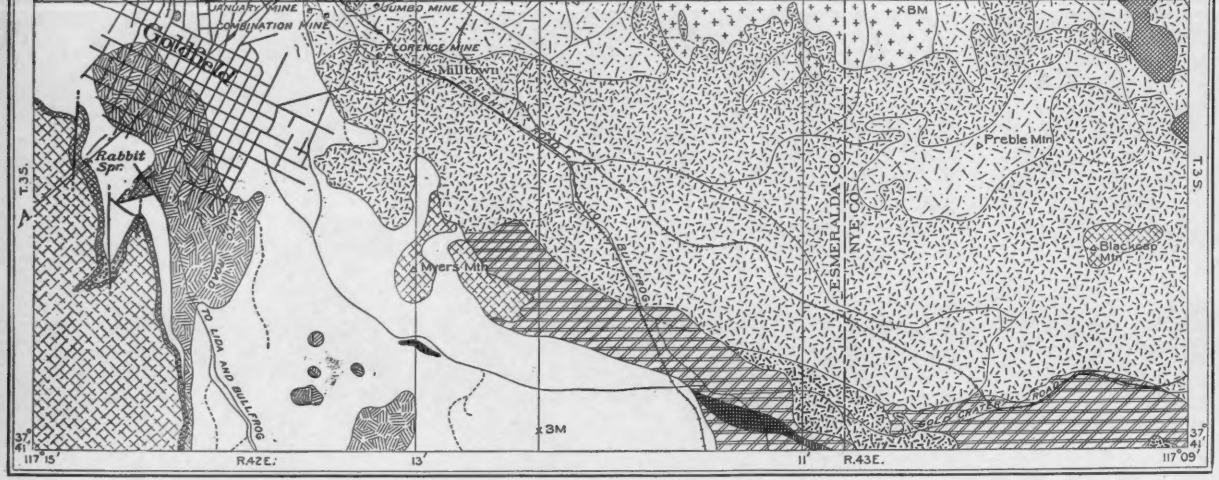
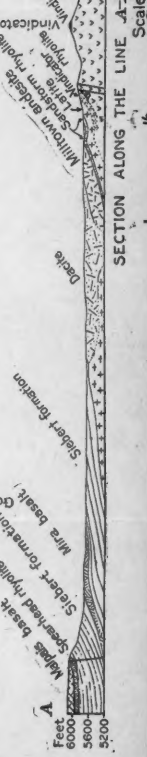


TION ALONG THE LINE A-B ON GEOLOGIC MAP FROM S.W. TO N.E.

Scale 0 ½ 1 mile





LEGEND

- Malpais basalt — *Chiefly olivine dolerite. Flows.*
- Spearhead rhyolite — *Flow or flows.*
- Pozo formation — *Fluviatile gravels and sands*
- Siebert formation — *Lake beds*
- Mira basalt — *Flow in Siebert formation*
- Espina breccia — *Pyroclastic. Dacitic in part*
- Andesite breccia — *Pyroclastic*
- Meda rhyolite — *Flow*
- Chispa andesite — *Flows intercalated in dacite vitrophyre*
- Dacite vitrophyre — *Flows*
- Dacite — *Intrusive. Passes into flows east of area mapped*
- Milltown andesite — *Flows and small intrusions*
- Morena rhyolite — *Intrusive*
- Sandstorm rhyolite — *Flows*
- Kendall tuff — *Rhyolitic and latitic*
- Latite — *Flows*
- Vindicator rhyolite — *Flow*
- Alaskite and granite — *Intrusive*
- Cambrian shale

Scale
½ 0 MILE
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GEOLOGIC MAP AND SECTION OF THE GOLDFIELD DISTRICT, NEVADA